National Aeronautics and
Space Administration

GODDARD SPACE FLIGHT CENTER

ENVIRONMENTAL TEST AND INTEGRATION FACILITIES HANDBOOK

OCTOBER 2000

GODDARD SPACE FLIGHT CENTER

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Code 549
http://sheds.gsfc.nasa.gov

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

Cover Photo: Spacecraft Systems Development And Integration Facility (SSDIF) Building 29 Cleanroom containing Hubble Space Telescope First Servicing Mission hardware returned from space. Panoramic photo by Dave Orbock.

INTRODUCTION

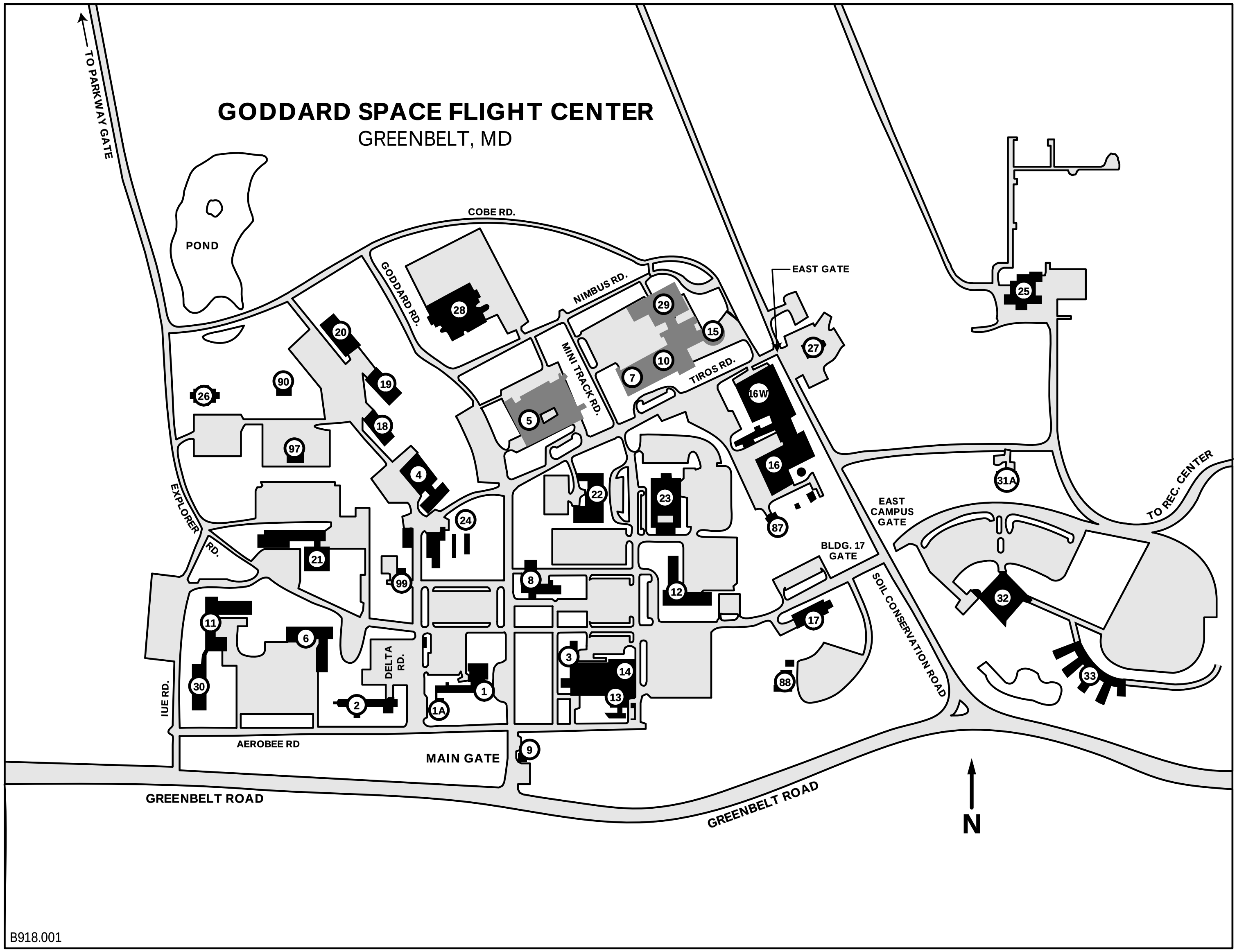
The mission of the Goddard Space Flight Center (GSFC) is to serve as a national resource for discovery in Earth Science, Space Science, and Technology Development. This mission is carried out through the use of scientific instruments, spacecraft, space shuttle attached payloads, sounding rockets, balloons, satellite servicing, and supporting ground systems. To fulfill this mission GSFC maintains the on-site capability to function as a full spectrum end-to-end research and development laboratory. Scientific missions can be carried out from concept, through design, manufacture, test, and operations. GSFC is committed through its strategic institutional goals to maintaining and upgrading GSFC's core infrastructure, laboratory facilities, and equipment to preserve the Center's preeminence as a national resource and Center of Excellence. The capabilities provided by the GSFC Environmental Test and Integration Facilities are a key element to realizing this goal.

The GSFC Environmental Test and Integration Facilities are managed by the Applied Engineering and Technology Directorate's Mechanical Systems Center to provide environmental test capability that ensures spacecraft and flight experiments will withstand the rigors of launch and will operate properly in the space environment. Integration and test programs also have the long-range goals of advancing the state-of-the-art of environmental testing and aiding in the development of improved space flight systems. The GSFC Environmental Test and Integration Facilities are one of the most complete and comprehensive complexes within the United States Government.

This handbook explains Goddard's Environmental Test and Integration capabilities and facilities. A layout map of GSFC, showing the building locations of these facilities, appears on the following page. Included as an Appendix is a User’s Guide that lists Organizational Contacts and explains how to obtain services from the Mechanical Systems Center Environmental Test and Integration Branch at Goddard.

Further information on Goddard's facilities and capabilities can be obtained from:

Assistant for Operations
Code 540
Goddard Space Flight Center
Greenbelt, Maryland 20771
(301) 286-8747



Environmental Test Engineering And Integration Branch - Bldgs 7, 10, 15, and 29

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1.0 ENVIRONMENTAL TEST ENGINEERING SERVICES AND FACILITIES

1.1 CAPABILITIES

The Environmental Test Engineering And Integration Branch provides facilities, instrumentation, data analysis, and test engineering of spacecraft, instruments, and components for environments induced by ground handling, launch, powered flight, and orbital operation. The Branch also conducts mass property, magnetic, and electromagnetic compatibility measurements that are required for determining spacecraft performance. The Environmental Test Engineering and Integration Branch's functions include three environmental test disciplines as follows:

Structural Dynamics:	Vibration Acceleration Acoustic Mechanical and static load Mass properties and spin balance Modal survey Data analysis (flight and ground data)
Electromagnetics:	Electromagnetic compatibility Magnetic
Space Simulation:	Thermal/vacuum Solar simulation Leak detection Molecular contamination monitoring Temperature/humidity control

Details of environmental test facilities and their capabilities are described in the following sections. Facilities are equipped with state-of-the-art computer network capabilities. Connections for Ethernet (10BASE2,10BASET and 100BASET) with access to the INTERNET and Point-to-Point Fiber Optics are available.

1.2 STRUCTURAL DYNAMICS
1.2.1 VIBRATION FACILITY

GENERAL: The Vibration Laboratory provides all necessary services and equipment to perform shock and vibration testing of spacecraft and subsystems. Digital control systems provide sinusoidal, random, and transient waveform control to four separate electrodynamic exciters. Data acquisition systems condition and record accelerometer, force, and strain gage signals. A small machine shop with drill press, milling machine, and band saw is used for simple fixture fabrication.

CONTROL SYSTEM: Digital vibration control systems process from 1 to 4 accelerometer signals and control on the minimum, maximum, rms, or average of the signals. A redundant accelerometer is always connected to an Unholtz-Dickie 123 vibration monitor limiter that has selectable acceleration and displacement limits for overtest protection.

CONTROL SYSTEM SINE & RANDOM PARAMETERS		
VIB PARAMETER	**SINE**	**RANDOM**
Frequency range:	5 Hz to 2 KHZ	10 Hz to 2 KHz
Output dynamic range:	72 dB	60 dB
Sweep rate, linear:	1 to 1,000 Hz/second	N/A
Sweep rate, log:	1 to 8 octave/minute	N/A
Break points per spectrum:	up to 99	up to 99
Loss of signal protection:	Automatic shut down	Automatic shut down

CONTROL SYSTEM TRANSIENT WAVEFORM PARAMETERS	
Pulse types:	Half-sine, sawtooth, triangular, trapezoidal, and user-defined
Pulse amplitude:	0.1 to 10,000 g (limited by exciter capability)
Pulse duration:	0.5 to 1,000 milliseconds

VIBRATION EXCITERS: Ling B-335 (2 each) and MB C-220 (2 each) exciters are located on isolated seismic blocks. Payloads up to 227 Kg (500 lb) are tested on the Ling B-335 exciters, and up to 4,082 Kg (9,000 lb) are tested on the MB C-220 exciters.

The Ling B-335 exciters share a common test cell, with one set up for vertical and the other set up for lateral testing. The lateral exciter drives a Team 1830 lateral slip table. An 1,814 Kg (2 ton) monorail crane services both exciters.

Each MB C-220 exciter is located in its own test cell, serviced by its own 6,804 Kg (7.5 ton) overhead bridge crane.

VIBRATION CONTROL SYSTEM

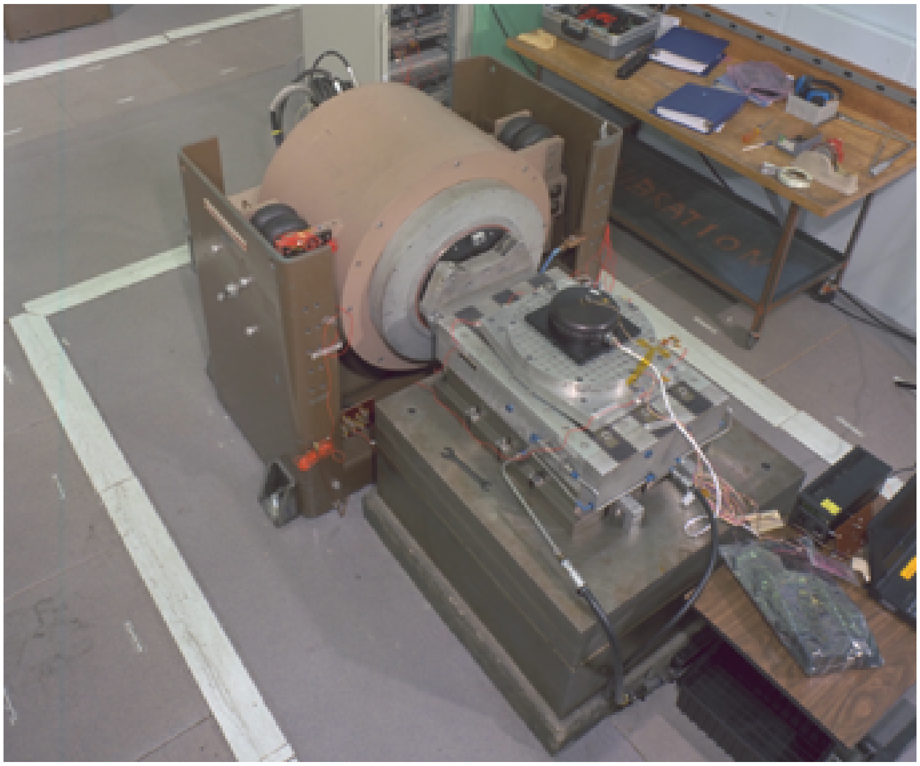
MB C-220 EXCITER #1

VIBRATION EXCITER & TEST CELL PARAMETERS		
PARAMETER	**LING B-335**	**MB C-220**
Force rating:	Sine vector - 78 K-newton (17,500 lbf) Random rms - 53 K-newton (12,000 lbf)	Sine vector - 156 K-newton (35,000 lbf) Random rms - 110 K-newton (24,700 lbf)
Exciter power amplifier:	A single Unholtz-Dickie SA120 PA (60 KVA) drives either exciter	A single Ling 8096 PA (192 KVA) drives either exciter
Displacement limit:	2.5cm (1.0") double amplitude	2.5cm (1.0") double amplitude
Velocity limit:	178cm/second (70"/sec)	178cm/second (70"/sec)
Frequency range:	5 Hz to 2 KHz	5 Hz to 2 KHz
Payload vertical centering:	Centers up to 907 Kg (2,000 lb) via pneumatic system	Centers up to 2,268 Kg (5,000 lb) via integral electrical system Centers up to 4,536 Kg (10,000 lb) via auxiliary airstroke actuator suspension system
Lateral slip table:	Team 1830 lateral slip table 74cm L x 51cm W (29" x 20") connected to the lateral exciter	Exciter #1: 127cm L x 127cm W (50" x 50") Team 483 table with 16 integral bearings Exciter #2: 178cm L x 168cm W (70" x 66") slip plate on 9 separate Team bearings
Test cell dimensions:	11.3m L x 4.6m W x 4.9m H (37' x 15' x 16')	8.8m L x 8.2m W x 15.5m H (29' x 27' x 51')
Crane capacity:	1,814 Kg (2 ton) monorail crane	6,804 Kg (7.5 ton) bridge crane
Access doors:	2.5m W x 4.9m H (8'3" x 16')	Upper door: 4.9m W x 9.0m H (16'2" x 29'5") Lower door: 2.5m W x 4.9m H (8'3" x 16')
Cleanroom capability (when required):	Payload can be bagged in special plastic with a purge system.	Payload can be bagged in special plastic with a purge system. Exciter #1 test cell can be operated as a class 10,000 cleanroom, but requires funding and extra time to clean and certify it before a test.

VIBRATION UPGRADE: A planned upgrade for the facility is scheduled for the spring of 2001. A new Unholtz-Dickie Model T4000 exciter will replace the existing MB C-220 exciter #1 and be connected to the existing Team 483 lateral table. The new shaker will have the following specifications:

Force rating:	178 K-newton (40,000 lbf) peak sine
	178 K-newton (40,000 lbf) rms random
Power amplifier:	Unholtz-Dickie Model 2XSAI120 (240 KVA expandable)
Displacement limit:	5.1cm (2.0”) double amplitude
Velocity limit:	178cm/sec (70”/sec) upgradeable to 216cm/sec (85”/sec)
Frequency range:	2 Hz to 2,000 Hz
Payload centering:	1,361 Kg (3,000 lb) via internal pneumatic vertical load support

MB C-220 EXCITER #2



LING B-335 EXCITERS

1.2.2 SIX DEGREE OF FREEDOM SHAKER FACILITY (Under Development)

DESCRIPTION: The six degree of freedom shaker facility consists of a Team Corporation Tube electro-hydraulic shaker system mounted on an isolated seismic block and an LMS Time Waveform Replication control system.

The Team shaker consists of a cylinder, 127cm (50") in diameter, approximately 127cm (50") high. The cylinder is supported internally by six integrated hydraulic shakers. Each shaker is coupled to the table through hydrostatic pad bearings that are designed to uncouple all degrees of fredom except axial translation. The system is therefore a true kinematic suspension. Each shaker is free to operate independently of the others.

The LMS Time Waveform Replication control system is used to compensate for the waveform distortion characteristic that is present in this, and all other, hydraulic vibration systems. The open loop control system starts with a desired acceleration time history waveform at the shaker/payload interface and pre-compensates the drive signal to each shaker so the resulting motion at the shaker/payload interface conforms to the specified time history. The initial pre-compensated drive signals are sent to the shakers, and the acceleration response at the shaker/payload interface is measured. The measured response is compared to the desired waveform and an error function is calculated. The drive signal is then adjusted based on this error function. This process is repeated until the resultant motion at the shaker/payload interface is acceptable.

APPLICATIONS: The six degree of freedom shaker system has many potential applications. It can be used to perform conventional single-axis tests with the advantage of needing to handle and set up the test item only once to complete a 3-axis test. The system can be used to perform multi-degree of freedom testing such as a combined translational and rotational test. The facility also provides a good platform for performing base-excited modal tests.

PARAMETERS: Six degrees of freedom: Three orthogonal in translation and three rotational (pitch, roll, yaw). The six hydraulic shakers are configured so that three are vertical and three are horizontal (in a delta configuration). Frequency range to 200 Hz; table displacements to 5.1cm (2.0") in translation and 0.12 radians in rotation; 15Klb-ft moment capacity; velocity 76.2cm/sec (30 in/sec). The piston area of each integrated shaker is 14.65cm^2 (2.27in^2.) This results in a peak or stall force of 50.5 K-newton (11,350 lbf) per actuator at 34.5 Mpa (5,000 psi) operating pressure. The sine force is rated conservatively at 33.4 K-newton (7,500 lbf.) The three vertical shakers provide a total force of 100 K-newton (22,500 lbf.) The three horizontal shakers combine their respective forces as a vector sum so the maximum horizontal force is 58.3 K-newton (13,100 lbf) in one horizontal direction, and 67.2 K-newton (15,100 lbf) in the other. The shaker table weighs 621 Kg (1,370 lb.) The maximum sinusoidal acceleration is therefore 16.5g in the vertical direction, 11.0g in one horizontal direction, and 9.5g in the other horizontal direction.

SIX DEGREE OF FREEDOM SHAKER FACILITY PARAMETERS	
Force rating (sinusoidal):	100 K-newton (22,500 lbf) vertical 67.2 K-newton (15,100 lbf) lateral 58.3 K-newton (13,100 lbf) longitudinal
Displacement limit:	5.1cm (2.0") double amplitude
Velocity limit:	76.2cm/sec (30"/sec)
Frequency range:	2 - 200 Hz
Shaker payload mounting area:	127cm (50") diameter
Test cell dimensions:	4.4m L x 4.4m W x 4.5m H (14'6" x 14'6" x 14'9")
Crane capacity (monorail):	1,814 Kg (2-ton)
Hook height:	4.5m (14'9") to floor 3.0m (10') to topside of shaker

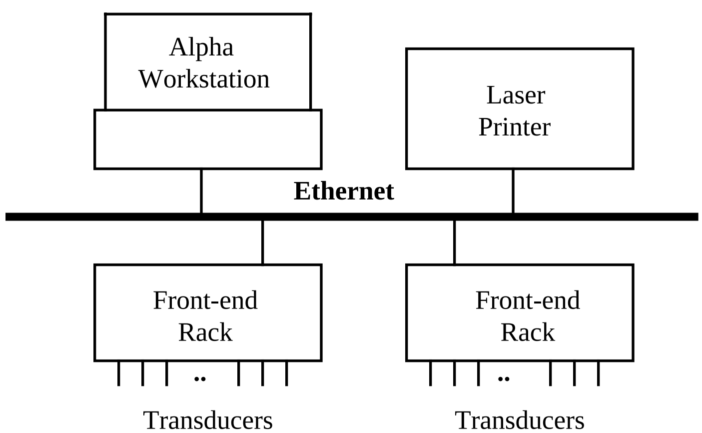
SIX DEGREE OF FREEDOM SHAKER

1.2.3 DIGITAL DATA ACQUISITION FACILITY

DESCRIPTION: The Digital Data Acquisiton Facility provides signal conditioning, recording, and data analysis capabilities for transducers used in vibration, acoustic, pyroshock, and other types of tests on-site at GSFC or at remote field sites. There are three systems currently available for use: the Digital Data Acquisition System (DDAS), the Digital Data Acquisition and Processing System (DDAPS), and the portable HP3565 System. All three systems are transportable, so they can be taken anywhere that measurements are needed.

A) DDAS: The Digital Data Acquisition System is a high frequency, multi-channel dynamic data acquisition system that has been designed specifically to support vibration, acoustic, and modal survey testing. The modular system can be configured to support more than one test at a time. The system has the following characteristics:

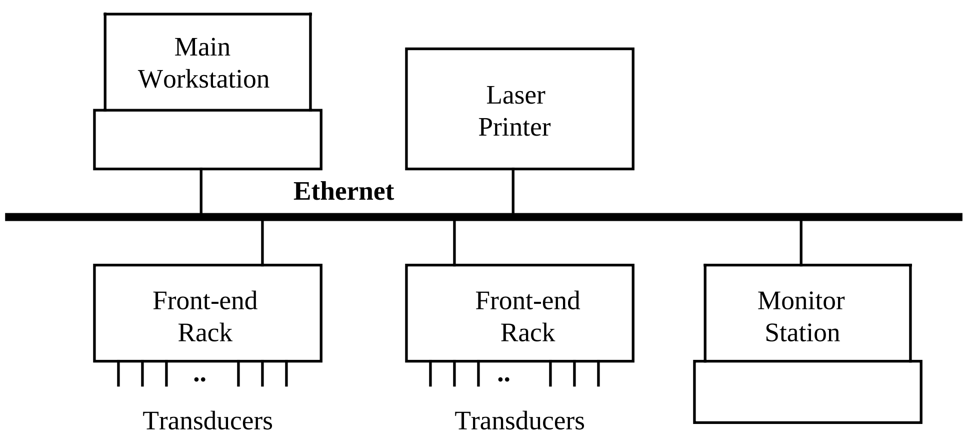
- Three front end racks.
- Each rack consists of 64 channels of signal conditioning, anti-aliasing filters, programmable gain amplifiers, analog-to-digital converters, and hard disk storage.
- Each channel can accommodate either up to ± 5 volts full scale or integrated circuit piezoelectronic (ICP) inputs.
- Each rack is controlled remotely by a workstation via Ethernet. Commands are transmitted to the individual modules from the workstation using TCP/IP.
- Data acquisition is initiated by command. Once data acquisition is initiated, the rack is capable of operating independently of the workstation, acquiring data until the desired amount is collected.
- During data acquisition, up to 16 channels at a time of real-time data can be transmitted to the workstation or X-terminal for display.
- The recorded data is transmitted to the workstation for processing using VAMP (Vibration Acoustic Modal Processor) software system. Off-line archiving of the data is accomplished by rewritable optical disks.
- Each rack can record 64 channels at 8,192 samples/second, 32 channels at 16,384 samples/second,16 channels at 32,768 samples/second, or 8 channels at 51,200 samples/second for 15 minutes.



DDAS BLOCK DIAGRAM

B) DDAPS (Proposed New System): The Digital Data Acquisition and Processing System is a high frequency, multi-channel dynamic data acquisition system that has been designed specifically to support vibration, acoustic, and modal survey testing. It is similar to the DDAS system, but can also process and display the data stream in real-time. The modular system can be configured to support more than one test at a time. The system has the following characteristics:

- One front-end rack (may be expanded.)
- Each rack consists of 64 channels of signal conditioning, anti-aliasing filters, analog-to-digital converters, and hard disk for data storage.
- Each channel can accommodate either voltage up to ± 5 volts full scale or integrated circuit piezoelectronic (ICP) inputs.
- Each rack is controlled remotely by the main workstation via Ethernet. Commands are transmitted to the individual modules from the main workstation using TCP/IP.
- Data acquisition can be initiated either by command or triggered by signal level. Once data acquisition is initiated, the rack is capable of operating independently of the workstation, acquiring data until the desired amount is collected.
- During data acquisition, up to 16 channels at a time of real-time time-history data may be transmitted to the main workstation or X-terminal for display.
- In addition, up to 16 channels at a time of real-time processed data can be transmitted to one or more monitor stations via Ethernet.
- Real-time processing includes power spectral densities, frequency response functions, and shock response spectra.
- The recorded data is transmitted to the main workstation for archiving. Off-line archiving of the data is accomplished by rewritable optical disks.
- Each rack can record 64 channels at a maximum sampling rate of 51,200 samples/second/channel for 15 minutes.



DDAPS BLOCK DIAGRAM

C) HP3565: The Hewlett-Packard 3565 signal analyzer is a high frequency, 16-channel dynamic signal analyzer system that has been designed specifically to support small vibration, acoustic, and modal survey tests. The system can be configured to acquire either time-histories or frequency analyzed results. The system has the following characteristics:

- Two front-end systems.
- Each front-end consists of 8 channels of signal conditioning, anti-aliasing filters, analog-to-digital converters, and hard disk for data storage. Two front-ends can be combined into a single 16-channel system.
- Each channel can accommodate either voltage up to ± 5 volts full scale or integrated circuit piezoelectronic (ICP) inputs with the addition of an external conditioner.
- Each front-end is controlled with a lap-top or desk-top computer with an HPIB interface.
- Data acquisition can be initiated either by manual or signal level triggering.
- Real-time processing includes power spectral densities and 1/3-octave spectrums.
- The system can record 16 channels with signal frequency from DC to 12.8 KHz for 1 minute, DC to 250 Hz for 1 hour, and various combinations in between.

DIGITAL DATA ACQUISITION SYSTEM (DDAS)

1.2.4 DATA REDUCTION LABORATORY

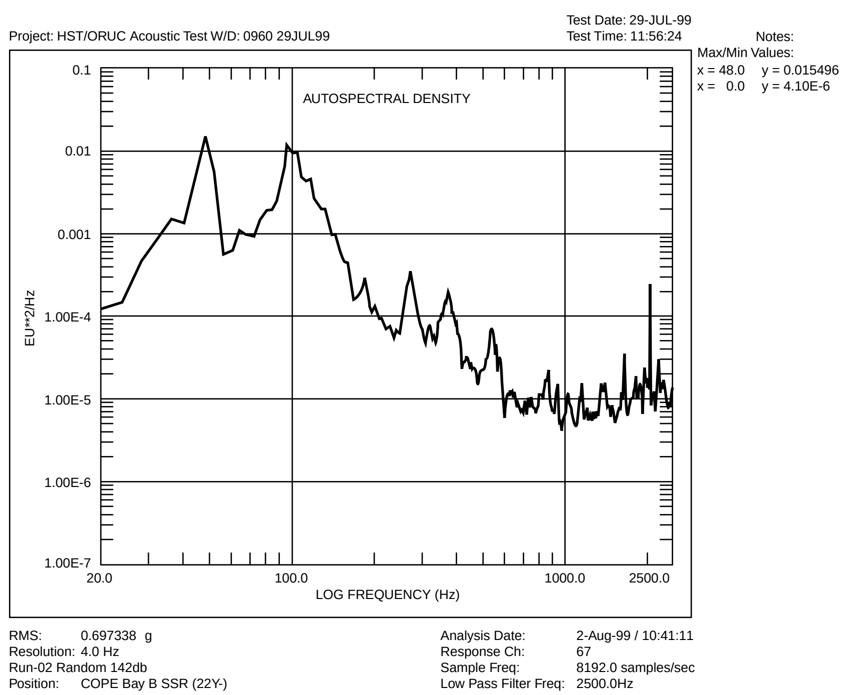
DESCRIPTION: The Data Reduction Laboratory digitizes analog signals or translates digitally recorded signals, and analyzes the data to produce plots in a useable form. In addition to the standard analyses of power spectral densities and frequency response functions, customized analysis can be performed such as filtering and relative displacements calculations.

DIGITAL DATA ACQUISITION: The equipment described earlier in the section entitled, "DIGITAL DATA ACQUISITION FACILITY" can be used for acquisition if the data is in analog form. A Sony AIT Tape Drive is available to record and play back lengthy time histories. A PCM decoder is also available.

ANALOG DATA PLAYBACK: The Reduction Laboratory has Honeywell Model 96 tape recorders that can be configured for FM, FM Multiplex, PCM, or direct playback or recording.

DATA ANALYSIS: Data analysis is performed on an AlphaServer 2100 named, "dynalpha." Data is transferred from the acquisition systems using Ethernet. I-DEAS Test Data Analysis Software is used for most data processing. MATLAB software is also available for data analysis and manipulation. There are C++ and FORTRAN compilers available for special application development.

DATA COMMUNICATION: Data is communicated among the systems in the Data Reduction Lab, Digital Data Acquisiton Facility, and user desk-top computers using Ethernet. The "dynalpha" computer is used as an anonymous FTP site for data transfer to outside activities. Data can be transmitted as I-DEAS Universal Files or Spreadsheet Text Files.



SAMPLE DATA ANALYSIS PLOT - AUTOSPECTRAL DENSITY

1.2.5 TRANSDUCER CALIBRATION LABORATORY

DESCRIPTION: This laboratory calibrates piezoelectric, piezoresistive, servo, and strain gage type accelerometers. It contains an Unholtz-Dickie calibration control system with a 1.33 K-newton (300 lb) force capacity exciter, and a Gyrex compound centrifuge.

MODE OF OPERATION:

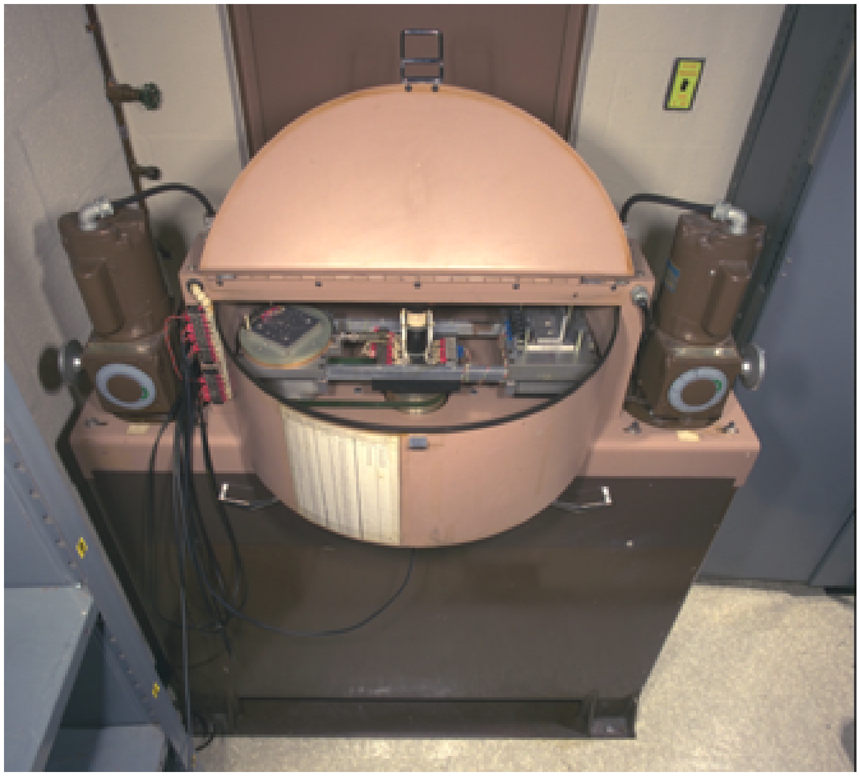
U-D Calibration System: Transfer standard reference accelerometers that are traceable to the National Institute of Standards and Technology (NIST) are used to determine the sensitivity of the U-D exciter reference accelerometer. Universal fixtures are used to mount unknown accelerometers on the exciter in a back to back configuration with the reference accelerometer. Automatic plots of the unknown accelerometer sensitivity versus frequency are produced by the calibration system.

Gyrex Compound Centrifuge: Servo-type, DC-responsive accelerometers are calibrated on the U-D system, and then used to cross check centrifuge acceleration parameters. Absolute g level is determined by measuring the radius to the center of gravity of the unknown transducer and using a digital frequency counter to adjust the centrifuge RPM levels to calculated values. For low frequency (1 Hz to 10 Hz) calibrations, the accelerometer is mounted on the compound rotating table.

PARAMETERS:

Parameter	U-D Calibration System	Gyrex Centrifuge
Acceleration:	up to 75g	up to 80g
Frequency range:	5 Hz to 5 KHz	0 to 10 Hz
Displacement/radius	1.78cm (0.7") double amplitude	20cm to 28cm (8" to 11")
Calibration accuracy:	± 3% overall system	± 5% overall system
Transducer size/weight:	up to 15cm (6") cube/0.9 Kg (2 lb)	up to 8cm (3") cube/2.3 Kg (5 lb)

DATA ACQUISITION: For both systems, one transducer at a time is calibrated. Multiple-axis transducers are calibrated one axis at a time. Digital voltmeters, X-Y plotters, and oscilloscopes display the transducer output signals. Cables interconnect the Transducer Calibration Lab to the Data Reduction Lab to facilitate special analysis techniques.



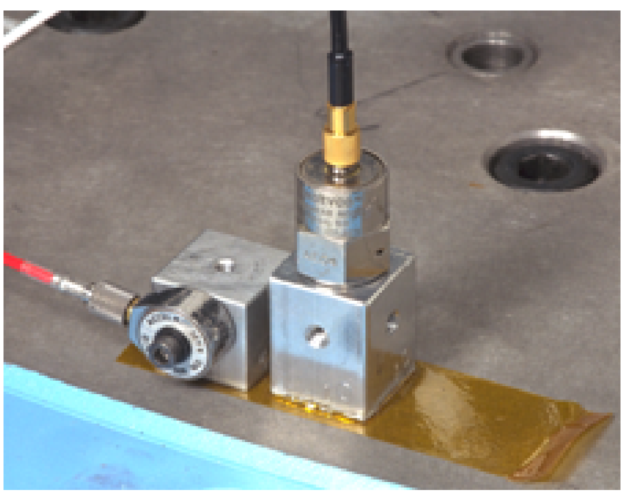
GYREX COMPOUND CENTRIFUGE

UNHOLTZ-DICKIE CALIBRATION SYSTEM

1.2.6 TRANSDUCERS

DESCRIPTION: The Structural Dynamics Section uses a variety of transducers to measure different environmental parameters. The table below lists typical transducer types along with typical specifications:

Transducer Type	Parameter	Typical Specifications
Accelerometer, piezoelectric	acceleration	0 to 5,000g, 1Hz to 5KHz
Accelerometer, servo/resistive	acceleration	0 to 50g, DC to 1KHz
Displacement (LVDT)	linear displacement	0 to 20.3cm (8")
Force gauge	force	0 to 99,680 newton (22,400 lb force)
Load cell	load (weight)	0 to 45,360 Kg (100,000 lb)
Microphone	sound pressure level	0 to 175 dB
Proximity sensor	linear displacement	0 to 0.25cm (0.1")
Strain gage	strain	0 to 1,270 microns (50,000 microinch)
Torque wrench transducer	torque	0 to 746 newton-meter (550 ft-lb)
Vibrometer, single point laser Vibrometer, scanning laser	velocity	DC to 300 KHz; 0.001 to 1,000mm/second



ACCELEROMETERS

VIBROMETER

1.2.7 BOLT ANALYZER

DESCRIPTION: The Bolt Analyzer is a portable, lap-top computer based sytem designed to measure various characteristics of bolts and bolted joints. Both Metric and English bolts can be measured. The analyzer instantly provides three important parameters: 1) torque factor (or friction) for virtually any bolted joint, 2) preload (or clamping force) in the bolt, and 3) torque.

MODE OF OPERATION: The Bolt Analyzer uses the industry standard formula:

$$T=KCD$$

where T = torque
K = torque coefficient (mostly friction)
C = Bolt preload (clamping force)
D = bolt nominal diameter

Torque and load data are measured real time during bolt torque-up. Torque coefficient is computed real time. Data points are stored as a function of bolt load and torque.

INTEGRAL INSTRUMENTATION: A variety of Wheatstone bridge type torque transducers and clamping force transducers are used to make real time measurements. National Instruments, Inc. analog-to-digital signal conditioners convert the transducer signals so they can be processed and stored on the lap-top computer.

PARAMETERS:

Bolt size capability:	3mm to 25mm	(Metric type)
	0.112" to 1.0"	(English type)
Torque measurements:	up to 678 newton-meter (500 ft-lb)	
Clamping measurements:	up to 27,216 Kg (60,000 lb)	

DATA ACQUISITION/ANALYSIS: Data points can be read directly from the computer screen. Tabulated data in the form of hard copy spread sheets can be prepared for each test run.

BOLT ANALYZER OPERATION

1.2.8 ACOUSTIC TEST FACILITY

DESCRIPTION: The Acoustic Test Facility tests various sized scientific satellites, subsystems, and components. It consists of the reverberation chamber, acoustic horns, noise generators, control console, and data handling system. The facility can be operated as a clean room (Class 100,000) once the payload access doors are closed and the facility is cleaned. An anteroom is used for changing into clean garments before entering the facility through the personnel door.

MODE OF OPERATION: The sound pressure level within the chamber is adjusted to the required spectrum. Small and medium sized payloads are suspended on the crane hook at the center of the chamber. Larger payloads are mounted on carts or fixtures. Four to eight control microphones are placed around the payload a minimum of 0.3m (1.0') away.

Acoustic energy is generated by modulating the flow of GN_2 through the generators attached to the horns. A fresh air, forced ventilation system stabilizes the chamber pressure during operation of the facility and purges the chamber of GN_2 for safe entry after the test.

PARAMETERS:

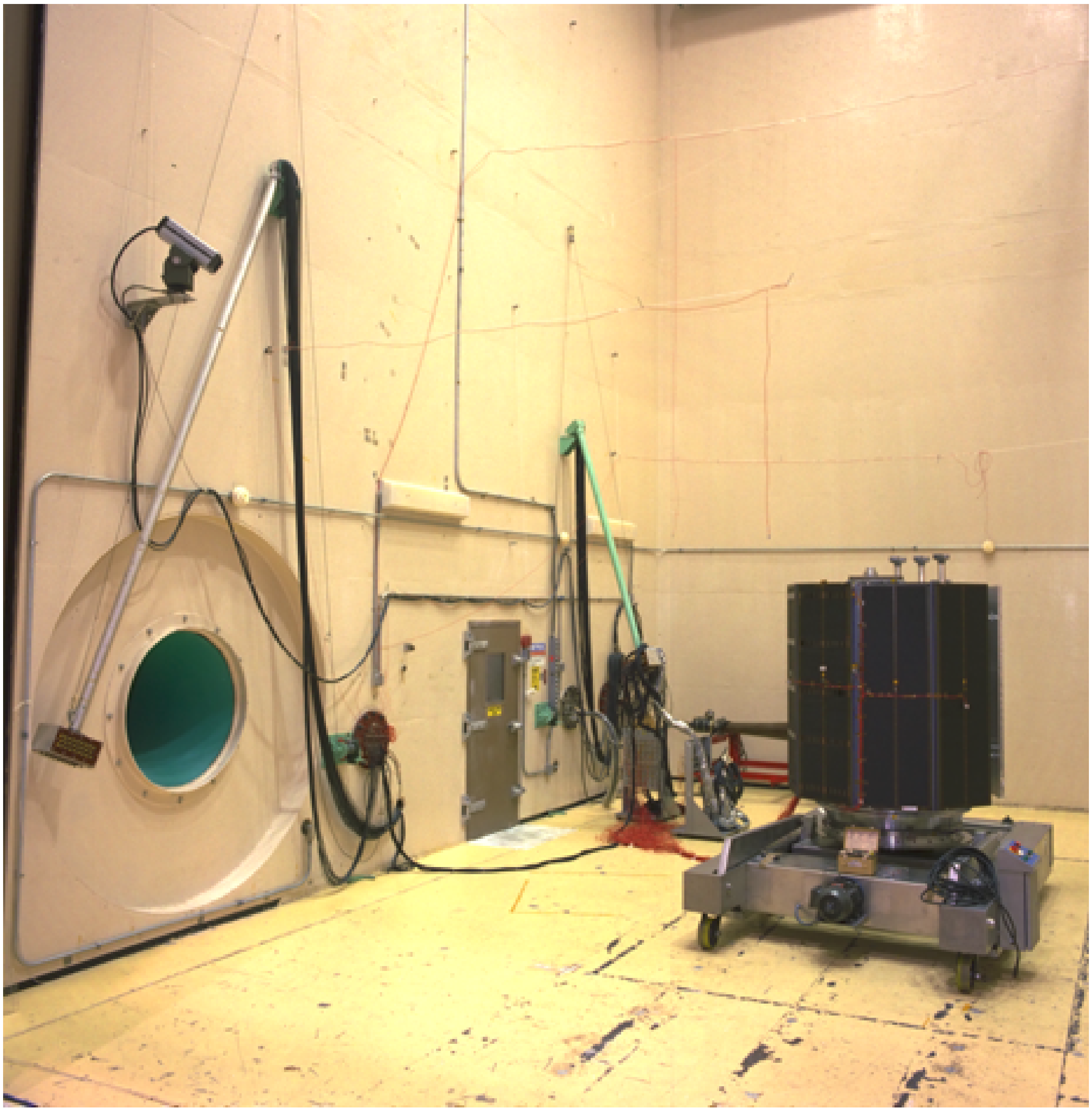
Generators (3):	3-10KW, electro-pneumatic
Horns (3):	25 Hz exponential, 50 Hz hypex, 75 Hz exponential
Maximum SPL:	150 dB overall sound pressure level
Frequency range:	25 Hz to 10 KHz

PHYSICAL CHARACTERISTICS:

Interior:	10.0m L x 8.2m W x 12.8m H (33' x 27' x 42')
Payload access:	4.92m W x 9.14m H (16’2" x 30')
Personnel door:	0.91m W x 1.98m H (3' x 6’6")
Crane capacity:	6,804 Kg (7.5 ton)

INTEGRAL INSTRUMENTATION: The software-based Acoustic Control System (ACS) precisely controls the spectrum of the sound pressure within the chamber in the real-time mode. The control system includes integral equipment such as the HP VXI hardware platform and associated control software, control microphones, signal conditioners, power amplifiers, acoustic generators, and horns. The ACS provides 100% digital control, without external bandpass filters or microphone multiplexer.

DATA ACQUISITION: Accelerometer, and strain gage signals are conditioned and acquired using the Digital Data Acquisition System (DDAS) in the Data Reduction Laboratory (DRL). Data signals are transmitted from DDAS front-end equipment located at the Acoustic chamber to the DRL via the Ethernet. A CCTV is available for observing and recording the payload during the test.



ACOUSTIC TEST CHAMBER

1.2.9 MASS PROPERTIES MEASUREMENT FACILITY (MPMF)

DESCRIPTION: The MPMF is used to measure the weight, center of gravity (CG), moment of inertia (MOI), and product of inertia (POI) of large structural assemblies. Also, the facility can be used to balance payloads statically and dynamically.

MODE OF OPERATION: The basic machine has a 1.22m (4') diameter mounting table. A 3.1m (10') table is also available for large payloads. The machine contains a spherical air bearing that supports the measuring table and the test item. A control console is connected to the MPMF by flexible cables and a GN_2 line.

A complete set of mass properties requires three separate setup configurations of the payload. This requires special fixturing and a turnover facility or other equipment to handle the payload.

<u>Weight Measurements</u>: The facility is mounted on a Pennsylvania 6600 scale base platform (1.75m L x 1.75m W x 0.1m H; 5.75' x 5.75' x 0.33') which gives an immediate digital readout of the weight of the test specimen, regardless of its mounting position on the facility.

<u>CG Measurements:</u> The static unbalance (CG offset) is determined by detecting the moment created by a CG displaced from the measurement axis of the machine.

<u>MOI Measurements:</u> The MOI is determined by using the facility as an inverted torsional pendulum, and measuring the period of oscillation about the geometrical axis of the machine.

<u>POI Measurement:</u> The POI (dynamic unbalance) is determined by rotating the payload on the MPMF at several different speeds, and measuring the moment.

INTEGRAL INSTRUMENTATION: Instrumentation consists of the control console. The control system measures the unbalance moment, period of oscillation, and table rotational speed.

FACILITY INTEGRATION: The MPMF is portable. It can be operated in cleanrooms, or remotely operated in vacuum chambers at pressures down to 1.33 Kpa (10 torr).

PARAMETERS:

Parameter	Specification
Test weight:	up to 4,536 Kg (10,000 lb)
Moment measurement range:	up to 3,390 newton-meter (30,000 in-lb)
CG capability:	± 0.15cm (0.06") for payload at 0.91m (3') above table and displaced 2.54cm (1") from vertical axis ± 0.3cm (0.12") for payload at 3.1m (10') above table and displaced 2.54cm (1") from vertical axis
MOI accuracy:	1% of measured MOI
POI accuracy:	5% of measured POI
MPMF table speed:	0 to 200 RPM
Platform scale capacity:	9,072 Kg (20,000 lb)
GN_2 flow rate:	$0.17m^3$/minute ($6.0ft^3$/minute) standard

MASS PROPERTIES MEASUREMENT FACILITY

1.2.10 HIGH CAPACITY CENTRIFUGE FACILITY

DESCRIPTION: The High Capacity Centrifuge (HCC) simulates launch and landing loads on spacecraft hardware. Primarily, payloads are installed on a test platform at the end of the centrifuge arm that has an adjustable tilt fixture. On infrequent occasions, the payload is installed in a cylindrical test chamber at the other end. The HCC is driven by one or two 0.93 Mw (1250 hp) DC motors operated in conjunction with a motor generator set. Controlled deceleration is possible by using the drive motor(s) in a regenerative mode.

MODE OF OPERATION:

1) Use 6,804 Kg (7.5 ton) crane to position test article on test platform.
2) Use adjustable tilt fixture to orient test article at proper attitude and angle.
3) Alternatively, mount payload in test chamber by attaching test article to removable end cap.
4) Pick up and position end cap using loading vehicle, and attach it to test chamber.

PARAMETERS:

	Chamber and Platform
Nominal test radius:	18.3m (60')
Maximum weight at 30 g:	2,268 Kg (5,000 lb); Includes weight of payload + fixturing
Maximum test acceleration:	30.0 g
Maximum speed:	30.0 RPM (1 motor) 38.3 RPM (2 motors)

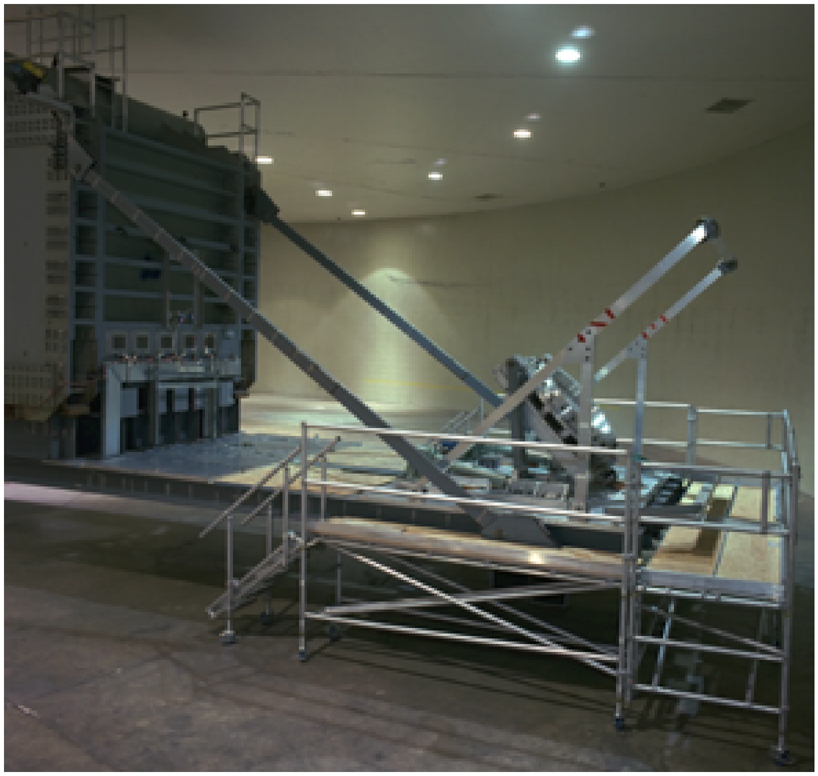
PHYSICAL CHARACTERISTICS:

Platform dimensions:	3.66m W x 6.40m L (12' x 21')
Platform height (above floor):	1.52m (5')
Test chamber size:	3.66m dia x 6.71m L (12' x 22')
Crane capacity:	6,804 Kg (7.5 ton)
Rotunda dimensions:	47.9m dia x 8.23m H (157' x 27')

Slip Rings

Instrumentation/control:	24 (5A) and 986 (1A)
Radio frequency:	6
Power:	30-100A @600V
CCTV system:	2

DATA ACQUISITION: The facility is serviced by the Hewlett-Packard (HP) VXI data acquisition system. Onboard the centrifuge arm, the VXI mainframe unit provides signal conditioning and data acquisition. In the HCC control room, the HP workstation provides test setup, instrumentation test control, data display, and data storage. The system is capable of various combinations of 160 channels of strain, deflection, and acceleration measurements. Also, CCTV and video recorders are provided.



HCC WEIGHT BUCKET TEST PLATFORM

HIGH CAPACITY CENTRIFUGE

1.2.11 UNIVERSAL STATIC TEST FACILITY

DESCRIPTION: The Universal Static Test Facility is a structural steel framework designed for the application of static loads to large shuttle-sized test items and payload handling assemblies.

MODE OF OPERATION: The test item is mounted in the facility using a 31,752 Kg (35 ton) overhead crane servicing the area. Pre-drilled reaction beams facilitate set up and operations. Strain gages and displacement transducers are installed and connected to the Hewlett-Packard (HP) VXI data acquisition system for monitoring. Hydraulic actuators and associated load monitoring devices and load links are installed between the structure and the test item. Loads are applied to the test item via manually-controlled hydraulic actuators. Removable structural members allow for both ease of test item installation and mounting of load application devices.

PARAMETERS: The facility is designed for the application of large loads associated with shuttle payloads. With some modification it is capable of loads of 36,288 Kg (80,000 lb). The structure can apply the following simultaneous test loads:

Vertical load:	Up to 11,794 Kg/beam (26,000 lb), 2 beams total
Lateral load:	Up to 18,598 Kg (41,000 lb)

PHYSICAL CHARACTERISTICS:

Internal test envelope:	6.7m L x 4.6m W x 4.6m H (22' x 15' x 15')
Facility weight:	19,958 Kg (44,000 lb)
Crane capacity:	31,752 Kg (35 ton), Building 29 overhead

DATA ACQUISITION: The facility is serviced by the HP VXI data acquisition system. The system is capable of various combinations of 160 channels of strain, deflection, and load measurements.

UNIVERSAL STATIC TEST FACILITY

1.2.12 SMALL STATIC TEST FACILITY

DESCRIPTION: The Small Static Test Facility is a structural test bed, designed for the application of static loads to payload components, sub-assemblies, and associated handling and lifting hardware.

MODE OF OPERATION: A crane or other suitable handling method is used to mount the test item in the facility. Strain gages and displacement transducers are installed and connected to the Hewlett-Packard (HP) VXI data acquisition system for monitoring. Hydraulic actuators and associated load monitoring devices and load links are installed between the structure and the test item. Loads are applied to the test item via manually-controlled hydraulic actuators. Removable structural members allow for both ease of test item installation and mounting of load application devices.

PARAMETERS: With minor modifications, the allowable loads can be increased as test requirements dictate. The structure can apply the following simultaneous test loads:

Vertical load:	Up to 9,072 Kg (20,000 lb)
Lateral load:	Up to 36,288 Kg (80,000 lb)

PHYSICAL CHARACTERISTICS:

Internal test envelope:	2.74m L x 2.74m W x 3.10m H (9' x 9' x 10')
Facility weight:	14,515 Kg (32,000 lb)
Crane capacity:	6,804 Kg (7.5 ton), Building 15 overhead crane

DATA ACQUISITION: The facility is serviced by the HP VXI data acquisition system. The system is capable of various combinations of 160 channels of strain, deflection, and load measurements.

SMALL STATIC TEST FACILITY

1.2.13 UNIVERSAL LOAD TESTING MACHINES

DESCRIPTION: Two Tinius Olsen universal load testing machines are used for tensile and compressive testing of small specimens, and for calibrating load cell transducers.

MODE OF OPERATION: The test specimen is attached to the crosshead using various types of hardware; for example, clamps, threaded rods, friction grips, eye bolts, and plates. Both tensile and compressive loads can be applied to the specimen, at a controlled rate, via a hydraulic ram (Machine #1) or a motor-driven crosshead (Machine #2).

PARAMETERS:

Machine #1 capacity:	0-54,432 Kg (120,000 lb); ± 1% accuracy
Machine #2 capacity:	0-27,216 Kg (60,000 lb); ± 1% accuracy

PHYSICAL CHARACTERISTICS:

Machine #1 test volume:	122cm L x 71cm W x 107cm H (48" x 28" x 42")
Machine #2 test volume:	122cm L x 71cm W x 107cm H (48" x 28" x 42")

INTEGRAL INSTRUMENTATION: Machine #1 has a digital servo control and a digital load readout. Machine #2 has analog control and an analog dial load readout. Both machines can produce plots of deflection or strain versus applied load.

LOAD TESTING MACHINE #2

1.2.14 MODAL SURVEY TEST FACILITY

DESCRIPTION: The Modal Survey Test Facility is used to measure dynamic response characteristics of aerospace structures. The facility consists of a seismic block on which test items are mounted to simulate a fixed boundary condition. A set of stanchions, mounted on the seismic block, provide boundary constraints simulating those of the Shuttle payload bay. The facility is serviced by three bridge cranes, which provide a convenient method of supporting up to four electrodynamic shakers, which are used to apply dynamic forces to the test item. The overhead structure which supports the bridge cranes may be used to suspend test items in a freely-supported test configuration. The facility has been used to apply a step relaxation technique in order to excite low frequency modes with significant energy.

The facility is supported by an instrumentation trailer, located adjacent to the seismic block. The trailer contains signal conditioning and data acquisition systems as well as shaker control systems. The trailer is connected via Ethernet to the Data Reduction Laboratory.

MODE OF OPERATION: The test item is mounted in the facility to simulate the desired constraint conditions. Excitation forces are applied to the test item at one or more driving point locations. Force gages are used to measure the excitation forces, while accelerometers are used to measure the response at selected locations. All of the measurement data is acquired and stored in the time domain format. Post test processing capabilities include frequency response functions, coherence functions, power spectra, etc. Modal parameters are obtained from various curve fitting algorithms which attempt to analytically describe the measured test data.

INTEGRAL INSTRUMENTATION: Instrumentation accelerometers, force gages, large and small impact hammers, large and small shakers, seismic accelerometers for floor surveys, signal conditioners, and monitoring oscilloscopes for all data channels.

PARAMETERS:

Excitation type:	random, sinusoidal, impact
Excitation load:	0 to 100 Kg (220 lb)
Frequency range:	2 Hz to 25 KHz
Resolution:	512 data points per frequency range
Shakers:	Force: Small - 23 Kg (50 lb); Large - 100 Kg (220 lb)
Impact hammers:	Force: Small - 0 to 227 Kg (500 lb); Large - 0 to 2,268 Kg (5,000 lb)

DATA ACQUISITION/ANALYSIS: Test data is acquired by digitally sampling the time domain signals from the accelerometers and force transducers. Accelerometer channels are manually switched in groups to acquire all of the required response measurements. Following acquisition, test data is processed using various techniques. One technique uses the fast Fourier transform to compute frequency response functions (FRFs). The FRFs, in turn, are curve fit using algorithms such as complex exponential, poly reference, etc. Other techniques available include random decrement, Ibrahim time domain and Eigenvalue realization algorithm.

MODAL FACILITY CONTROL SYSTEM

MODAL SURVEY TEST FACILITY

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1.3 ELECTROMAGNETIC TEST
1.3.1 ELECTROMAGNETIC COMPATIBILITY TESTING

INTRODUCTION: Two anechoic shielded testing facilities are available for conducting electromagnetic compatibility (EMC) tests. These facilities meet electromagnetic performance requirements specified by MIL-STD-462, and support the performance of EMC tests specified by MIL-STD-461 and the GSFC “General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components” (GEVS). Both facilities provide very low interior noise level ambient electromagnetic environments and the ability to contain internally-generated, radiated electromagnetic waves. All electrical power, communications, and other facility wiring are filtered; the facility structures are locally bonded to earth ground; and ventilation ducts and other apertures are designed as waveguide-below-cutoff. Contamination-sensitive items are tested in the Large EMC Facility (cleanroom), or they are bagged in non-reflective materials if tested in the Small EMC Facility, or provided with portable clean tents and blowers for a Class 10,000 environment.

INTEGRAL INSTRUMENTATION: Generated interference measurements are typically made using a Hewlett-Packard (HP) spectrum analyzer-based receiver system (HP 8566B and 85865A) for data acquisition, processing, and data reduction. Associated electric and magnetic field antennas and line conduction transducers are provided for testing in the 20 Hz to 18 GHz frequency range. The receiver system is controlled by the HP 85869A EMI measurement software package. Special test equipment is also available for testing from 18-40 GHz. Line conducted and radiated susceptibility tests are performed using a variety of signal generators, amplifiers, and transducers or antennas for injection and/or radiation of the test signals. Frequency range is 30 Hz to 400 MHz for signal injection; 10 kHz to 18 GHz for signal radiation; and 18-40 GHz for special applications. Radiated field strengths to 100V/m at 1 meter can typically be provided. Programmed swept frequency test signals, appropriately modulated, are provided over portions of the test spectrum.

DATA ACQUISITION: Emissions test data is recorded in a swept spectrum analog format on the HP 8566B and reduced to logarithmic versus frequency printout, including a specification limit when applicable, by the HP 85869A EMI measurement software package. The combined HP 8566B and 85869A measurement system is used for radiated and conducted emissions measurements. Susceptibility test data relating to the susceptibility test signal can be time synchronized with the test item performance test data which is typically recorded as a function of the type of ground support equipment furnished with the test item. Failure modes are test project defined and susceptibility thresholds determined whenever the test item responds to the susceptibility test signal.

ELECTRICAL POWER: Test item power is normally provided by project-furnished, current and/or voltage limited power supplies. Test item DC power (rechargeable battery) can be furnished upon project request and guarantees that adequate test item protection is being provided — particularly as line resonances can occur during conducted susceptibility tests. A 50 A-max/100 A-hour and a 100 A-max/600 A-hour battery system are available at 28 ±4 VDC and a 2V increment up to 36VDC (600 A-hour unit.)

1.3.1.1 SMALL EMC FACILITY

DESCRIPTION: This facility consists of three contiguous electromagnetically shielded enclosures and an adjoining Computer Room. It is located in the basement of Building 7 in Room 8 and is designed for either small satellite or sub-assembly tests. The individually shielded enclosures include the anechoic Test Room, the EMC Control Room, and a Ground Support Equipment (GSE) Room. The Test Room walls and overhead are covered with ferrite tiles and polyurethane wedge absorbers, which provide a minimum of 20dB absorption of normally-incident, above 20MHz, electromagnetic waves. A 2.5m long, 1m wide, copper-clad, test item mounting bench and cable access panel are located along/on the wall separating the Test Room from the GSE Room.

MODE OF OPERATION: The test article is installed in the Test Room and bonded to either the copper work bench or to the test article holding fixture and the metallic floor. Interconnecting cables between the test article and its ground support equipment are either connected through access panel-mounted connectors or via two cable ducts (9cm diameter). Project-furnished test article power line break-out boxes are typically required.

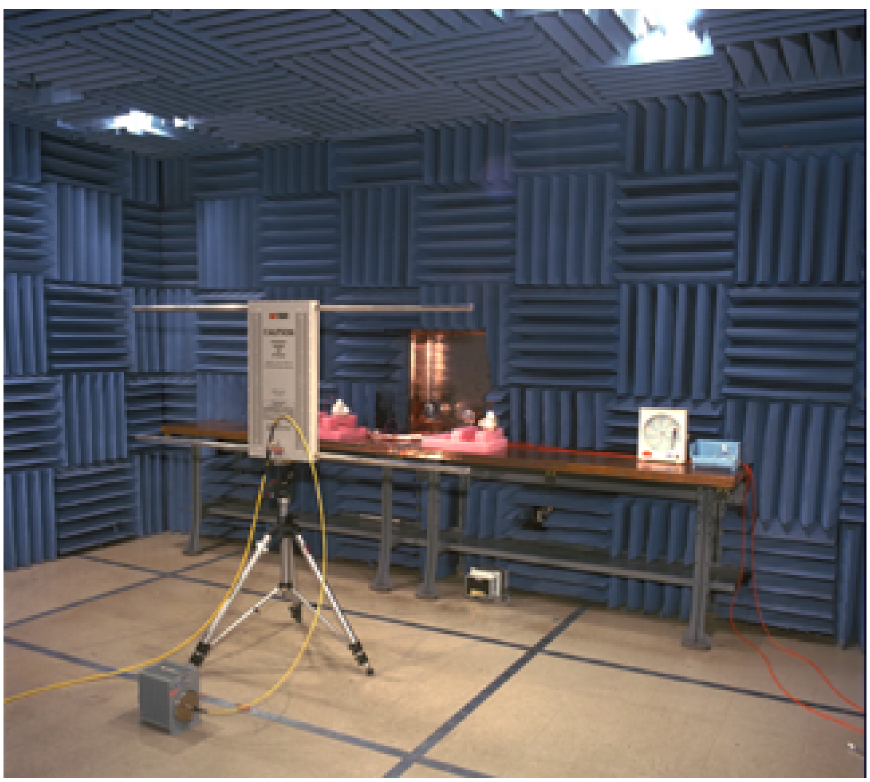
PHYSICAL CHARACTERISTICS:

Experimenter's area: 4m (L) x 2m (W) x 3m (H)	Personnel door: 1m (W) x 1.7m (H)
Control room: 7.3m (L) x 3.7m (W) x 3m (H)	Personnel door: 1.3m (W) x 2.1m (H)
Test area room: 5.5m (L) x 5m (W) x 3m (H)	Equipment door: 2m (W) x 2.2m (H)

Test Area Anechoic Characteristics: Ferrite tiles and carbon-impregnated polyurethane wedge blocks mounted on the interior walls of the test area combine to make the facility a broadband anechoic chamber capable of absorbing electromagnetic waves over the frequency range of 10 MHz to 40 GHz. Field measurement accuracy is thereby enhanced compared to shield room facilities that lack the anechoic material, and radiated susceptibility test signals are controlled with improved signal-to-noise ratios.

Fire Protection: Fire protection is provided in the Test Area using retractable sprinkler heads and an auto-cutoff ventilation system for toxic smoke exhaust to the outside of the building. Personnel safety features include a radiation hazard warning and monitoring system. The facility is also equipped with electrostatic discharge testing and prevention capabilities and a large copper test bench for mounting and earth-bonding test items.

SMALL EMC CONTROL CONSOLE



SMALL EMC SHIELDED ENCLOSURE

1.3.1.2 LARGE EMC FACILITY

DESCRIPTION: This facility is located in the northwest corner of the Building 7 test laboratory area and includes the shielded, anechoic Test Enclosure Room 108A; the shielded Ground Support Equipment (GSE) Room N117, the shielded EMC Control Room N115, and the unshielded Data Reduction Room N115. The facility is designed for testing large satellites requiring a high level of contamination protection and either Class 10,000 or Class 100,000 performance as specified for a particular test article. This results in more efficient operations as air showers and full gowning of test personnel is not required as is necessary to sustain Class 10,000 operation. The Test Enclosure consists of an outer standard modular shielded enclosure constructed of plywood paneling sandwiched by an inner and outer layer of galvanized steel and an excellent earth bond. Inside this enclosure is a patterned ferrite tiled 20-1000 MHz-effective anechoic enclosure which minimizes electromagnetic wave reflections in this frequency range. Within this enclosure are four corner-sectioned moveable microwave-absorber panels which are positioned so as to surround the test article and provide a minimum 6.5m cubed actual test enclosure.

MODE OF OPERATION: The test article is installed inside the ferrite enclosure with the microwave absorber panels rolled back. Ground support equipment connections are made through an access panel between the GSE Room and the Test Enclosure either by using a waveguide-below-cutoff cable duct, project-specific panel-mounted connectors, or a set of connectors that duplicate the thermal-vacuum chamber connectors (to allow commonality of cable harnesses). The EMC instruments are also connected through an access panel connecting between the Control Room and the Test Enclosure and between the Control Room and the Data Reduction Room. The test article is bonded to the metallic floor of the Test Enclosure and the earth bonding impedance and room ambient electromagnetic noise are measured and required to be a minimum of 6dB below the test frequency spectrum test limits.

PHYSICAL CHARACTERISTICS:
Test Enclosure Size: Expandable from basic 6.5m cubed. Max Height: 6.7m
Ferrite-Tiled Anechoic Enclosure Door Size: 6.5m (W) x 6.2m (H)
Ground Support Equipment Enclosure: Room Size: 6.7m (L) x 5.2m (W) x 3.2m (H
Door Size: 2m (W) x 2.5m (H)

SAFETY FEATURES: The Test Enclosure is equipped with flashing warning lights at all entrance doors to warn personnel not to enter whenever electromagnetic waves are being propagated within the room. Internal humidity and temperature alarms, as well as a fire alarm and dry sprinkler system, are also features of this facility.

LARGE EMC CONTROL CONSOLE

LARGE EMC SHIELDED ENCLOSURE

1.3.2 MAGNETIC TESTING

INTRODUCTION: The remotely located Magnetics Test Site contains two major coil systems, 6.7m (22') and 12.8m (42'), used for magnetic testing of payloads ranging from fully-configured spacecraft down to component level assemblies; and for calibrating torque coils and magnetometers in attitude control systems. Both facilities are 3-axis Braunbek coil systems consisting of 12 coils (four coils for each of three orthogonal axes.) Each coil contains windings for Earth's field cancellation, static and dynamic field generation, diurnal variation control, temperature gradient compensation, external gradient compensation, and two sets of spare windings.

Control consoles for both coil systems are located in a separate building apart from the coils. This isolation prevents control equipment magnetic fields from degrading the specified magnetic environment established within the Braunbek coils. For both coils, static and dynamic (0-100 rad/sec) field vectors can be generated along any axis with magnitudes up to 60,000 nanotesla (nT.)

1.3.2.1 6.7M (22') COIL MAGNETIC TEST FACILITY

DESCRIPTION: The Magnetic Field Component Test Facility (MFCTF) contains a 6.7m (22') diameter spherical coil system. This system provides geomagnetic field cancellation within a 0.9m (3') diameter sphere to levels described below. This coil system is used primarily for testing smaller satellites, performing instrument-level dipole moment measurements, and for calibrating magnetometers and attitude control systems.

MODE OF OPERATION: For a typical magnetometer test, a zero field is established in the center of the coils before the test unit is installed. A reference standard proton magnetometer is then used to calibrate the system. Following this, the test magnetometer is positioned on the platform at the center of the coil and aligned to the coil axes. Finally, static and dynamic fields are generated to establish the linearity, frequency response, zero offset, and alignment characteristics of the magnetometer.

PARAMETERS:

Static Field Capability		**Dynamic Field Capability**	
Magnitude (each axis):	± 60,000 nanotesla	Magnitude (each axis):	± 60,000 nanotesla
Resolution:	± 0.1 nanotesla	Resolution and stability:	± 2%
Stability:	± 0.5 nanotesla	Frequency:	0 to 100 rad/sec
Homogeneity:	0.001% (0.91m, 3' dia spherical volume)		

PHYSICAL CHARACTERISTICS:

Coil access opening:	1.52m W x 1.52m H (5' x 5')
Building access opening:	3.05m W x 3.05m H (10' x 10')

INTEGRAL INSTRUMENTATION: The MFCTF is equipped with instrumentation for the calibration and alignment of magnetometers. This instrumentation includes fluxgate and proton magnetometers for zeroing and calibrating. A data acquisition/analysis system is available to acquire the magnetometer data, perform near field analysis, and produce a customer-ready report.

6.7M (22') COIL CONTROL CONSOLE

6.7M (22') COIL MAGNETIC FACILITY

1.3.2.2 12.8M (42') COIL MAGNETIC TEST FACILITY

DESCRIPTION: The Spacecraft Magnetic Test Facility (SMTF) 12.8m (42') coil system is one of the three known spherical coil systems of this size in the world. Its geomagnetic field cancellation system is capable of cancelling the Earth's magnetic field within a 1.83m (6') diameter sphere. The SMTF also has a set of 2.90m (9'6") diameter Helmholtz coils available for perming and deperming spacecraft, and 1.22m (4') and 1.83m (6') diameter coils for magnetically cleaning smaller test items.

MODE OF OPERATION:

Magnetic Dipole Moment Testing: Zero field is first established in the center of the coil. A reference standard proton magnetometer is used to calibrate the coils. For each measurement sequence, the test item and facility dolly are moved to the center of the coil. As the dolly is rotated 360 degrees, three-component magnetic field data is obtained at 10-degree increments. The data are then stored in the computer for immediate display and processing. If the test item exceeds its test limit, compensation magnets can be developed to reduce the dipole moment to acceptable levels.

Spacecraft Magnetometer Calibration: Initial setup is similar to magnetic dipole moment testing. The test item is positioned in the center of the coil and aligned with the coil axes. Static and dynamic fields are generated to establish linearity, frequency response, zero offset, and alignment characteristics of the test item. The data system can be used to collect, store, and display test parameters.

PARAMETERS:

Static Field Capability		Dynamic Field Capability	
Magnitude (each axis):	± 60,000 nanotesla	Magnitude (each axis):	± 60,000 nanotesla
Resolution:	± 0.1 nanotesla	Resolution and stability:	± 2%
Stability:	± 0.5 nanotesla	Frequency:	0 to 100 rad/sec
Homogeneity:	0.001% (1.83m, 6' dia spherical volume)		

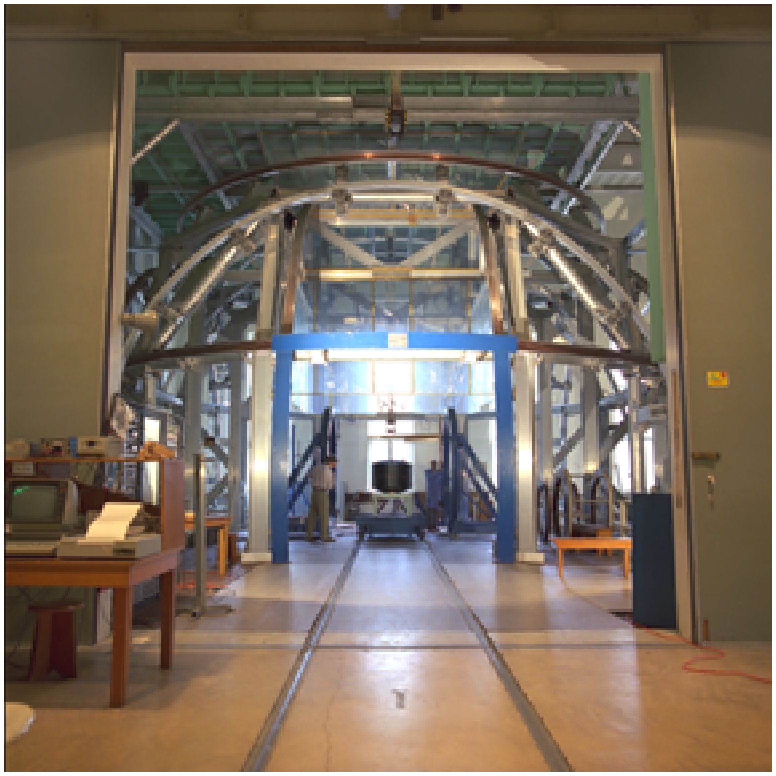
PHYSICAL CHARACTERISTICS:

Coil access opening:	3.05m W x 3.05m H (10' x 10')
Building access opening:	4.27m W x 4.57m H (14' x 15')
Hoists lifting capacities (4):	4,536 Kg (5 ton), 2,722 Kg (3 ton), and two each 2,268 Kg (2.5 ton)

INTEGRAL INSTRUMENTATION: The SMTF is equipped with single and triaxial magnetometers, proton magnetometers, torquemeter, and data collection instrumentation. It contains the three Helmholtz coils described above, with their associated AC and DC power supplies.

DATA ACQUISITION: An array of three state-of-the-art triaxial fluxgate magnetometers is used for magnetic field testing. A field mapping of the test item is performed, the resultant data is automatically provided as input into the facility's "near field analysis" software, and an equivalent dipole moment is calculated. Measurements are taken for various magnetic field conditions including: perm, deperm, induced and stray field (test item powered) measurements.

12.8M (42') COIL CONTROL CONSOLE



12.8M (42') COIL MAGNETIC FACILITY

1.4 SPACE SIMULATION TEST ENGINEERING

INTRODUCTION

This section provides a summary of the environmental capabilities and dimensions of the test facilities of the Space Simulation Test Engineering Section. The test facilities are operated and monitored 24-hours per day by operators.

It should be noted that the test volume measurements of each facility are the nominal dimensions of the thermal shroud, unless there is no shroud, and that the evacuation times are for a clean, dry and empty chamber. These data indicate the maximum capabilities of a facility. Lesser levels and decreased rates can be accomplished to accommodate payload requirements.

BUILDING 7 THERMAL VACUUM CHAMBERS VIEW

1.4.1 CAPABILITIES SUMMARY (SI UNITS)

FACILITY		NOMINAL SPECIFICATIONS (SI UNITS)			
Type	Number	Test Volume (meters)	Operating Pressure (pascal)	Temperature Range (° C)	Unique Capabilities
Temperature	204	0.51 x 0.31 x 0.41	Ambient	-180 to 200	
Temp/Humid	232	1.22 x 1.22 x 1.22	Ambient	-80 to 150	Humidity 15% to 95% RH
Thermal Vacuum	225	2.74 Dia. x 4.27 L	<13.3 μpa	-190 to 150	Cryopump, Turbopump, C/F, TQCM, RGA
	237	2.13 Dia. x 2.44 L	<67 μpa	-190 to 100	C/F, TQCM, RGA
	238	3.40 Dia. x 4.32 H	<67 μpa	-190 to 100	Cryopump, C/F, TQCM, RGA
	239	2.13 Dia. x 2.44 L	<67 μpa	-190 to 100	Cryopump, C/F, TQCM, RGA
	240	0.91 Dia. x 0.91 L	<13.3 μpa	-140 to 110	C/F, TQCM, RGA
	241	0.91 Dia. x 0.91 L	<13.3 μpa	-140 to 110	Cryopump, C/F, TQCM, RGA
	243/244	0.61 Dia. x 0.61 H	<67 μpa	-190 to 100	C/F, TQCM, RGA
	281	0.91 Dia. x 1.22 L	<13.3 μpa	-150 to 150	Cryopump, C/F, TQCM, RGA
	290	8.23 Dia. x 12.2 H	<13.3 μpa	-180 to 100	8 Cryopumps, 1 Turbopump
Rapid Pump Down	208	NA	1.33 pa	NA	Rough down Facilities 237 & 239 in 2 minutes
Thermal Conditioning Units	201	NA	NA	-140 to 140	GN_2 Transfer medium, circulating
	205	NA	NA	-100 to 100	GN_2 Transfer medium, single pass
	207	NA	NA	-100 to 100	GN_2 Transfer medium, single pass
	230	NA	NA	-150 to 150	GN_2 Transfer medium, circulating
Heater Racks	242	NA	NA	-100 to 100	Electrical heater controller
	315	NA	NA	-200 to 200	Electrical heater controller
Solar Simulator Portable	211	NA	NA	NA	61cm dia, 1 SC
	213	NA	NA	NA	33cm dia, 1 SC
Emergency Power	253	NA	NA	NA	250 KVA, 480V, 3-phase
	254	NA	NA	NA	500 KVA, 480V, 3-phase
High Press GN_2	257	NA	NA	NA	13.8 Mpa
	258	NA	NA	NA	13.8 Mpa

1.4.1 CAPABILITIES SUMMARY (ENGLISH UNITS)

FACILITY		NOMINAL SPECIFICATIONS (ENGLISH UNITS)			
Type	Number	Test Volume (feet)	Operating Pressure (torr)	Temperature Range (° F)	Unique Capabilities
Temperature	204	1.67 x 1.00 x 1.34	Ambient	-292 to 392	
Temp/Humid	232	4 x 4 x 4	Ambient	-112 to 302	Humidity 15% to 95% RH
Thermal Vacuum	225	9 Dia. x 14 L	$<10^{-7}$	-310 to 302	Cryopump, Turbopump, C/F, TQCM, RGA
	237	7 Dia. x 8 L	$<5 \times 10^{-7}$	-310 to 212	C/F, TQCM, RGA
	238	11Dia. x 14 High	$<5 \times 10^{-7}$	-310 to 212	Cryopump, C/F, TQCM, RGA
	239	7 Dia. x 8 L	$<5 \times 10^{-7}$	-310 to 212	Cryopump, C/F, TQCM, RGA
	240	3 Dia. x 3 L	$<10^{-7}$	-220 to 230	C/F, TQCM, RGA
	241	3 Dia. x 3 L	$<10^{-7}$	-220 to 230	Cryopump, C/F, TQCM, RGA
	243/244	2 Dia. x 2 High	$<5 \times 10^{-7}$	-310 to 212	C/F, TQCM, RGA
	281	3 Dia. x 4 L	$<10^{-7}$	-238 to 302	Cryopump, C/F, TQCM, RGA
	290	27 Dia. x 40 High	$<10^{-7}$	-292 to 212	8 Cryopumps, 1 Turbopump
Rapid Pump Down	208	NA	10^{-2}	NA	Rough down Facilities 237 & 239 in 2 minutes
Thermal Conditioning Units	201	NA	NA	-220 to 284	GN_2 Transfer medium, circulating
	205	NA	NA	-148 to 212	GN_2 Transfer medium, single pass
	207	NA	NA	-148 to 212	GN_2 Transfer medium, single pass
	230	NA	NA	-238 to 302	GN_2 Transfer medium, circulating
Heater Racks	242	NA	NA	-148 to 212	Electrical heater controller
	315	NA	NA	-328 to 392	Electrical Heater Controller
Solar Simulator Portable	211	NA	NA	NA	24" dia, 1 SC
	213	NA	NA	NA	13" dia, 1 SC
Emergency Power	253	NA	NA	NA	250 KVA, 480V, 3-phase
	254	NA	NA	NA	500 KVA, 480V, 3-phase
High Press GN_2	257	NA	NA	NA	2,000 psi
	258	NA	NA	NA	2,000 psi

1.4.2 TEMPERATURE - HUMIDITY
1.4.2.1 0.057M^3 (2FT^3) TEMPERATURE CHAMBER (FACILITY 204)

DESCRIPTION: This facility is a small temperature controlled chamber used for thermal conditioning of small components. The portable chamber loads through a front opening door that has a viewing window. The instrumented payload is installed in the chamber with no special handling or mounting fixtures, and is connected to the ground support equipment via a port.

MODE OF OPERATION: The chamber is cooled with liquid nitrogen and heated with electrical resistance elements.

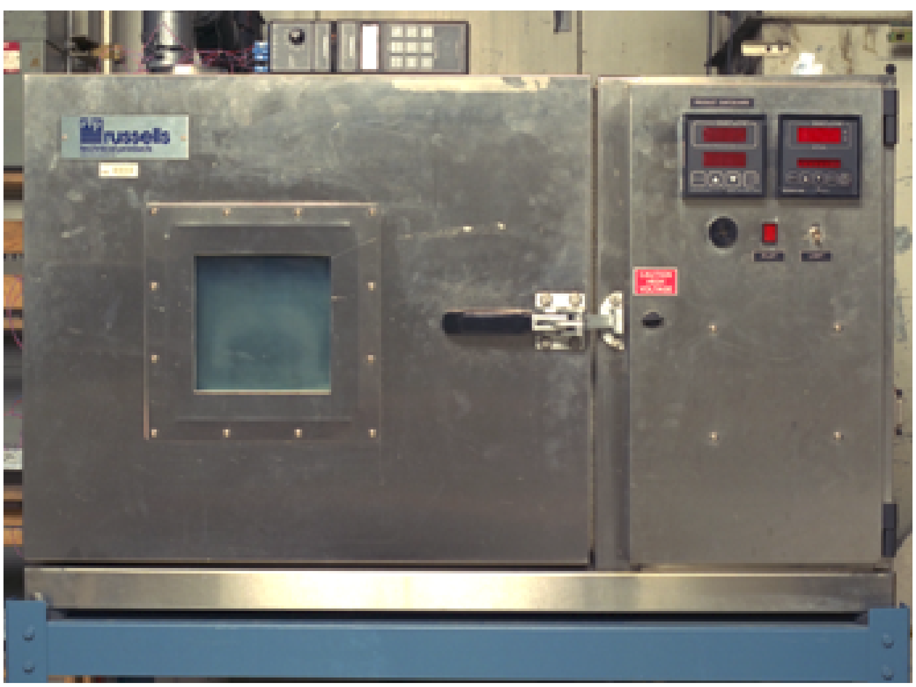
PARAMETERS:

Temperature range:	-180°C to 200°C (-292°F to 392°F)
Heating capacity:	510 watts
Cooling capacity:	100 watts at -150°C (-238°F)
Accuracy:	± 5°C (± 9°F)

PHYSICAL CHARACTERISTICS:

Test volume:	0.51m W x 0.31m H x 0.41m L (20" x 12" x 16")
Access port size:	6.35cm diameter (2.5")
Viewport size:	20cm x 20cm (8" x 8")
Power:	120 VAC, 1 phase, 20 amperes

INTEGRAL INSTRUMENTATION: Temperature and humidity are controlled by a digital programmer/controller located on the side of the chamber. Eighteen thermocouples are available for payload monitoring.



TEMPERATURE CHAMBER (FACILITY 204)

1.4.2.2 1.81M³ (64FT³) TEMPERATURE - HUMIDITY CHAMBER (FACILITY 232)

DESCRIPTION: This facility is a medium-sized chamber used for thermal and humidity cycling of medium-sized test items. A full-opening, hinged front door with a window allows for access and viewing.

MODE OF OPERATION: The test item is installed in the chamber and connected to an external power source and data acquisition equipment via an access port. After ambient functional checks are completed, electrical heaters warm, and a cascade refrigeration system cools the air stream. A separate cooling unit provides dehumidification, and an electrically heated vapor generator provides humidification. The preferred procedure is to operate the chamber with a hot cycle before decreasing the temperature below 4°C (39°F). A dry nitrogen purge system regulates humidity in the chamber to prevent frost build-up on the test item. Five integral gloves are provided in the front door of the chamber for "glove box" type testing of mechanisms, etc.

PARAMETERS:

Temperature range:	-80°C to 150°C (-112°F to 302°F)
Humidity range (RH):	15% to 95% (between 85°C (185°F) max and 4°C (39°F) min dewpoint)
Heating capacity:	18 Kw
Cooling capacity:	22 Kw

PHYSICAL CHARACTERISTICS:

Test volume:	1.22m W x 1.22m H x 1.22m L (4' x 4' x 4')
Viewport size:	61cm x 61cm (24" x 24")
Access port size:	15.2cm inside diameter (6")

INTEGRAL INSTRUMENTATION: Temperature and humidity are controlled by a digital programmer/controller located on the side of the chamber. Eighteen thermocouples are available for payload monitoring.

TEMPERATURE - HUMIDITY CHAMBER (FACILITY 232)

1.4.3 THERMAL VACUUM

1.4.3.1 3.1M X 4.6M (10' X 15') THERMAL VACUUM CHAMBER (FACILITY 225)

DESCRIPTION: This is a horizontal loading thermal vacuum test chamber used for thermal vacuum and thermal balance testing, and baking out large test items. Electrical feedthroughs and liquid and gas penetrations are provided at locations on the front, sides, and rear of the chamber. A clean tent covering the door opening provides a Class 10,000 clean area for integrating hardware prior to loading it into the chamber.

MODE OF OPERATION: Test items are loaded by crane onto a load cart, which is rolled into the chamber on a rail system. Payload weight can be as high as 2,268 Kg (5,000 lb). The chamber door remains open while thermocouples are installed on the test item inside the chamber. A temperature controlled baseplate may be provided for high thermal dissipation. Access to the chamber is through a clean tent. The use of cleanroom procedures and the wearing of clean garments are required when working in the chamber.

Chamber evacuation is provided by 2 cryopumps and 1 turbomolecular pump. Roughing is provided by a blower and rotary piston mechanical pump. Shroud temperature conditioning is accomplished by a recirculating GN_2 thermal system, or it may be flooded with LN_2.

PARAMETERS:

Test pressure:	<13.3 µpa (1 x 10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-140°C to 150°C (-220°F to 302°F)
LN_2 mode:	-190°C (-310°F)
Chamber pumping speed:	40,000 lit/sec (84,800 cfm) @ 133 µpa (10^{-6} torr)
Turbomolecular pumping speed:	1,000 lit/sec (2,120 cfm) @ 133 µpa (10^{-6} torr)

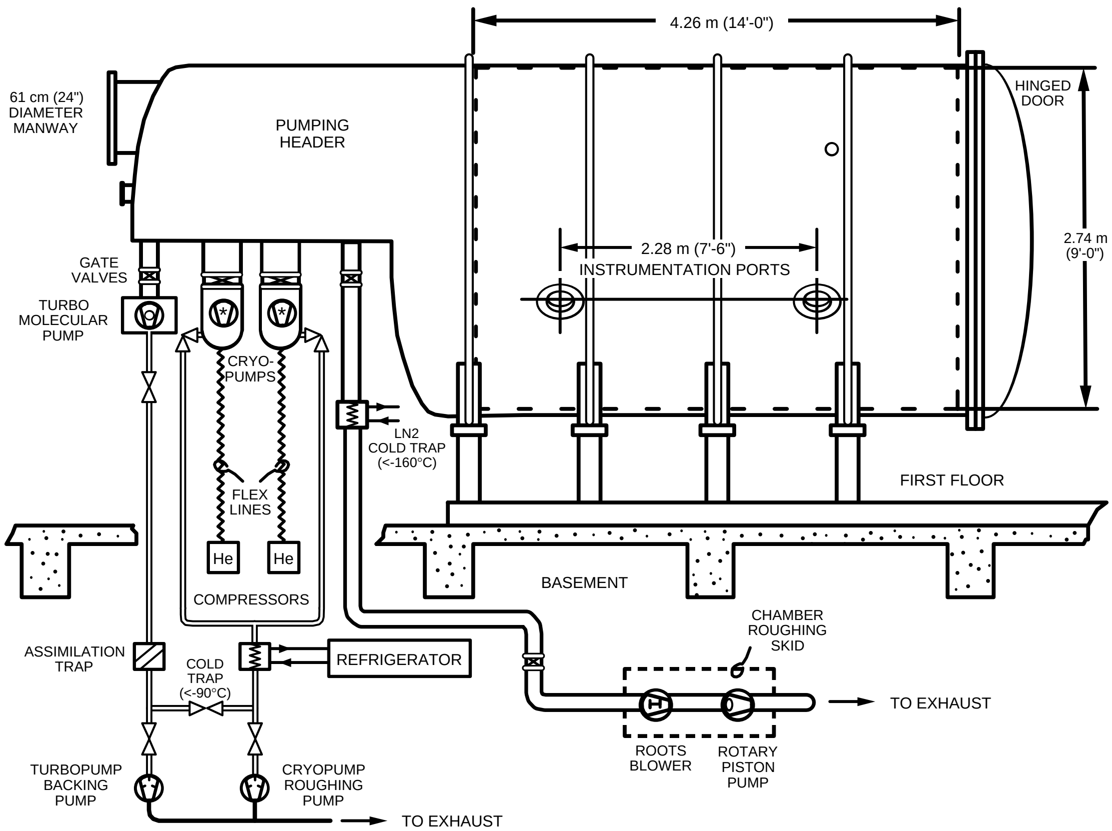
PHYSICAL CHARACTERISTICS:

Test volume:	2.74m dia x 4.27m L (9' x 14')
Payload support:	Wheeled cart - 2,268 Kg capacity (5,000 lb)
Instrumentation ports:	6 each 25.4cm dia (10"), 6 each 12.7cm dia (5")
Std. electrical feedthroughs:	37-pin, 7-pin, 4-pin, RF

INTEGRAL INSTRUMENTATION:

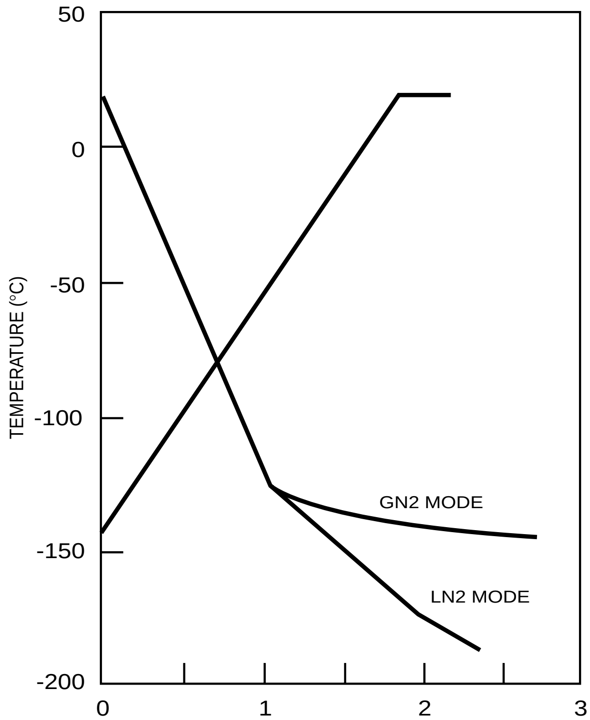
Pressure:	Capacitance manometer - atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	200 thermocouple channels
Contamination:	TQCM, cold finger, residual gas analyzer

AUXILIARY EQUIPMENT: Portable thermal systems are available to control baseplates, the thermoelectric quartz crystal microbalance (TQCM) and contamination control mirrors.

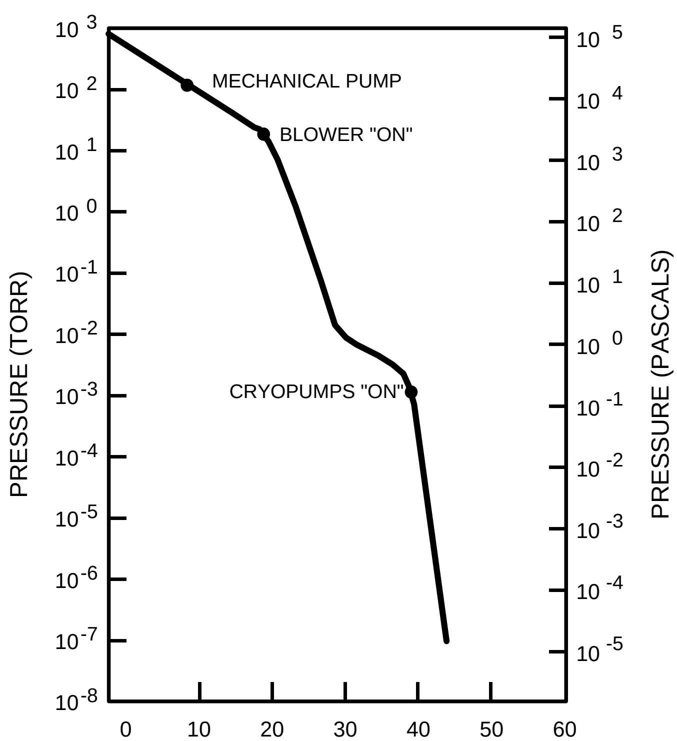


CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 225

10' X 15' CHAMBER (FACILITY 225)



TIME (HR.)
SHROUD TEMPERATURE
PERFORMANCE



TIME (MIN.)
FAC. 225 PUMPDOWN

1.4.3.2 2.1M X 2.4M (7' X 8') DIFFUSION PUMPED VACUUM CHAMBER (FACILITY 237)

DESCRIPTION: This is a horizontal loading thermal vacuum test chamber equipped with a viewport to accommodate an external solar simulator. The facility is used for thermal vacuum and thermal balance testing, and baking out test items. Any of two solar simulators may be used for tests with solar requirements.

MODE OF OPERATION: The test item is mounted on the portable payload fixture which is positioned at the chamber door. An overhead rail is also available for mounting purposes. The payload is instrumented with thermocouples and rolled into the chamber. Ground support equipment cabling is connected through the penetration plates and ambient functional checks are performed. Prior to solar testing, it is normal to perform an alignment check of the test item with the external simulator.

Chamber evacuation is provided by a rotary piston mechanical pump and an oil diffusion pump. Rapid pump down can also be performed. A sliding gate main valve allows chamber access while the pumping systems are established.

PARAMETERS:

Test pressure:	<67 µpa (5 x 10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-140°C to 100°C (-220°F to 212°F)
LN_2 mode:	-190°C (-310°F)
Chamber pumping speed:	25,000 lit/sec (53,000 cfm) @ 133 µpa (10^{-6} torr)
Evacuation time:	Atm to 133 µpa (10^{-6} torr) in 300 minutes

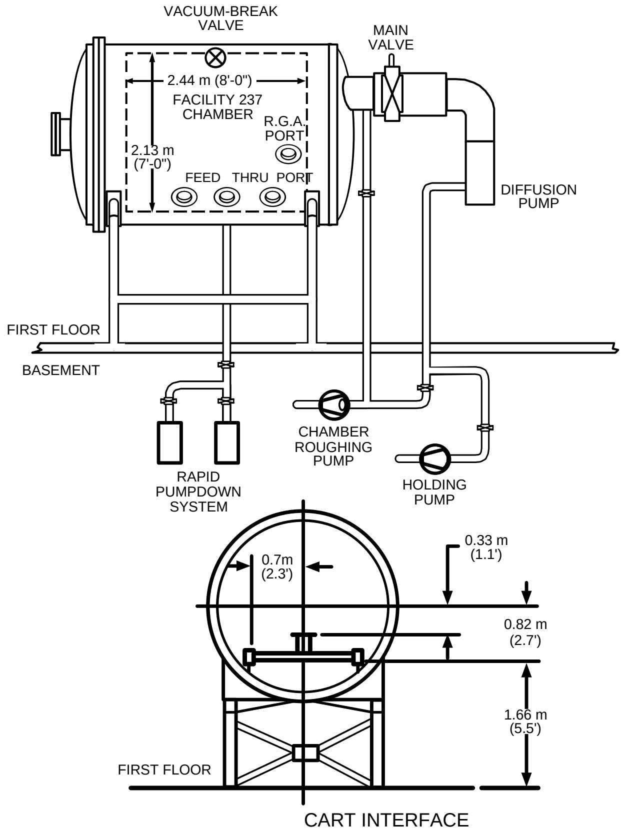
PHYSICAL CHARACTERISTICS:

Test volume:	2.13m dia x 2.44m L (7' x 8')
Viewport dimensions:	31cm dia (12") quartz window
Std. electrical feedthroughs:	37-pin, 7-pin, 4-pin, RF

INTEGRAL INSTRUMENTATION:

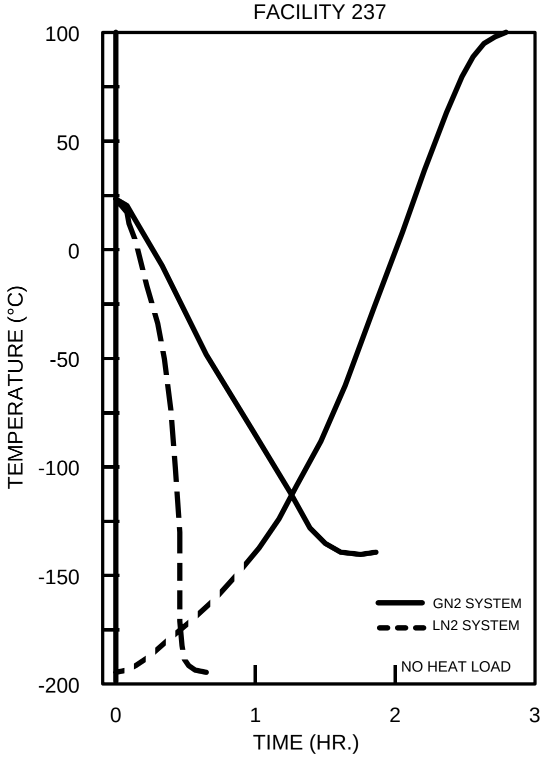
Pressure:	Capacitance manometer - atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	126 thermocouple channels
Contamination:	TQCM, cold finger, residual gas analyzer

AUXILIARY EQUIPMENT: Portable thermal systems are available to control baseplates, the thermoelectric quartz crystal microbalance (TQCM), and contamination control mirrors. A portable clean tent can be installed over the payload and facility entrance during test setup. All portable solar systems can be used.

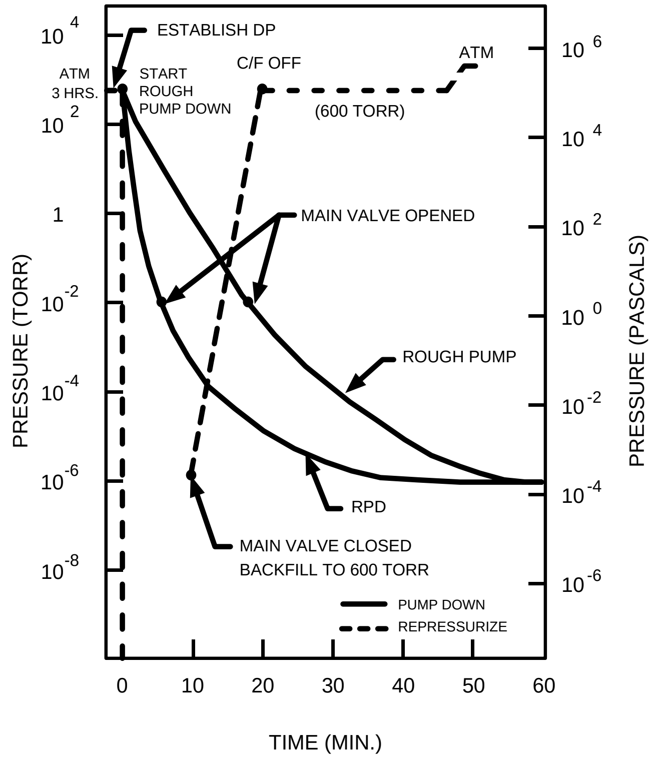


CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 237

CHAMBER VIEW



SHROUD TEMPERATURE PERFORMANCE



PRESSURE PARAMETERS

A918.004

1.4.3.3 3.7M X 4.6M (12' X 15') CRYOPUMPED VACUUM CHAMBER (FACILITY 238)

DESCRIPTION: This ia a vertical loading thermal vacuum test chamber used for thermal vacuum and thermal balance testing, and baking out spacecraft hardware. Test articles are normally loaded through the top of the chamber using the building crane; however, small payloads can be transported through the personnel entrance. Ports for electrical feedthroughs, liquid/gas feedthroughs, and viewing are located around the perimeter of the chamber. A clean tent at the chamber entrance provides class 10,000 cleanliness conditions.

MODE OF OPERATION: With the chamber dome rolled back, the overhead crane is used to lower the payload onto the support fixture. In most cases, special fixturing must be designed due to the uniqueness of the test article support system. Once installed, the payload is instrumented and connected to the ground support equipment via feedthroughs. Access to the chamber is through a clean tent. The use of cleanroom procedures and the wearing of clean garments are required when working in the chamber.

Initial chamber evacuation is provided by two rotary piston mechanical pumps, with four closed cycle cryopumps for high vacuum pumping. Each cryopump is isolated from the chamber by a sliding gate main valve to allow off-line cool down and regeneration.

PARAMETERS:

Test pressure:	<67 μpa (5 x 10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-90°C to 100°C (-130°F to 212°F)
LN_2 mode:	-190°C (-310°F)
Chamber pumping speed:	60,000 lit/sec (127,200 cfm) @ 133 μpa (10^{-6} torr)
Evacuation time:	Atm to 133 μpa (10^{-6} torr) in 2 hours

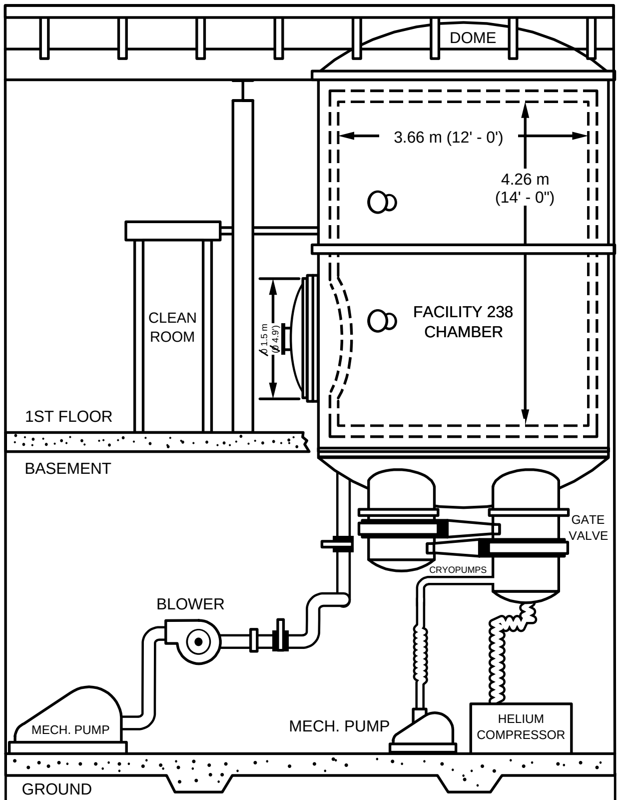
PHYSICAL CHARACTERISTICS:

Test volume:	3.4m D x 4.3m H (11’2" x 14’2")
Payload support:	Floor level - 1.2m (4') square platform
	Side wall - hard points at 1.8m and 3.7m (6' and 12') levels
Personnel door:	1.5m (5') diameter
Crane capacity:	4,536 Kg (5 ton)
Viewport dimensions:	23cm (9") diameter
Std. electrical feedthroughs:	37-pin, 7-pin, 4-pin, RF

INTEGRAL INSTRUMENTATION:

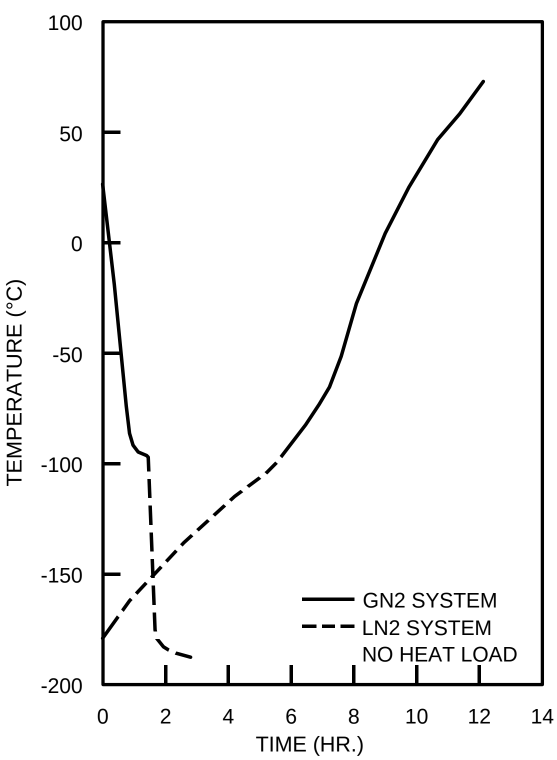
Pressure:	Capacitance manometer - Atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	300 thermocouple or thermistor channels
Contamination monitor:	TQCM, coldfinger, residual gas analyzer

AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.

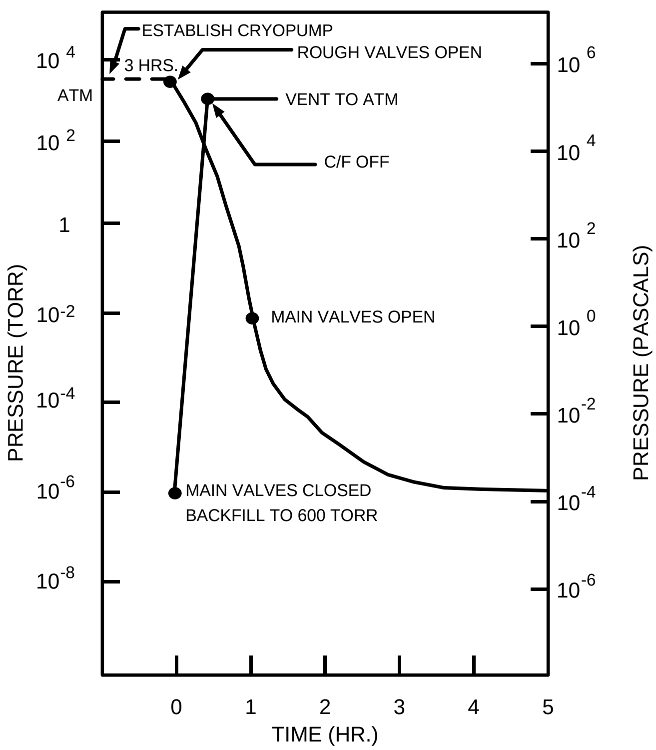


CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 238

CHAMBER VIEW



SHROUD TEMPERATURE
PERFORMANCE



PRESSURE PARAMETERS

A918.005

1.4.3.4 2.1M X 2.4M (7' X 8') CRYOPUMPED VACUUM CHAMBER (FACILITY 239)

DESCRIPTION: This horizontal loading thermal vacuum test chamber is equipped with a viewport to accommodate an external solar simulator. Chamber evacuation is provided by a rotary piston mechanical pump and cryopumping system. A sliding gate main valve allows chamber access while the cryopumping system is being established. The facility is used for thermal vacuum and thermal balance testing, and baking out test articles. Any of two solar simulators may be used for tests with solar requirements. A clean tent at the chamber entrance provides class 10,000 cleanliness conditions.

MODE OF OPERATION: The test article is mounted on the portable payload fixture which is pre-positioned at the chamber door. An overhead rail is also available for mounting purposes. After instrumenting the payload with thermocouples, it is rolled into the chamber. Ground support equipment cabling is connected through the penetration plates, and ambient functional checks are performed. Access to the chamber is through a clean tent. The use of cleanroom procedures and the wearing of clean garments are required when working in the chamber.

PARAMETERS:

Test pressure:	<67 µpa (5 x 10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-140°C to 100°C (-220°F to 212°F)
LN_2 mode:	-190°C (-310°F)
Chamber pumping speed:	20,000 lit/sec (42,400 cfm) @ 133 µpa (10^{-6} torr)
Evacuation time:	Atm to 1.3 pa (10^{-2} torr) in 1 hour
	1.3 pa to 133 µpa (10^{-6} torr) in 5 hours

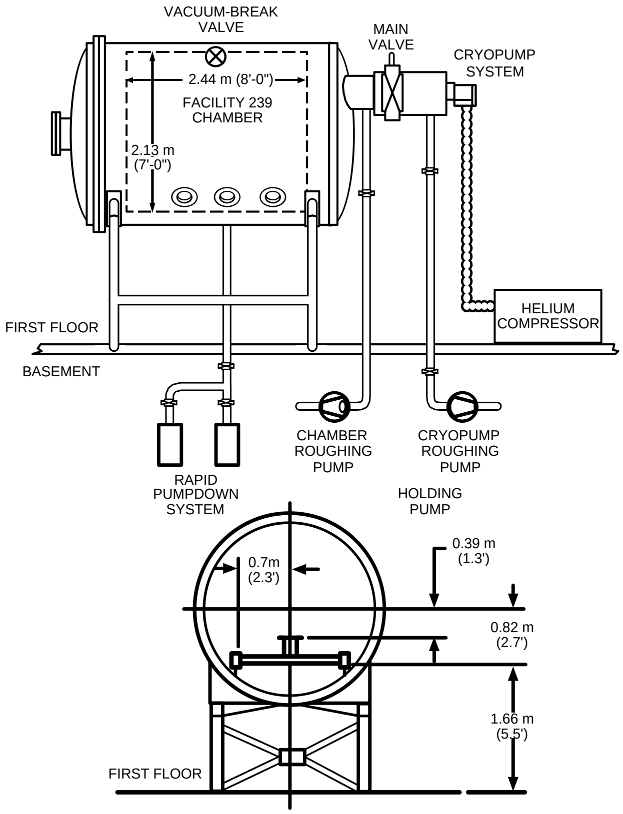
PHYSICAL CHARACTERISTICS:

Test volume:	2.13m diameter x 2.44m L (7' x 8')
Viewport dimensions:	30cm (12") diameter quartz window
Std. electrical feedthroughs:	37-pin, 7-pin, 4-pin, RF

INTEGRAL INSTRUMENTATION:

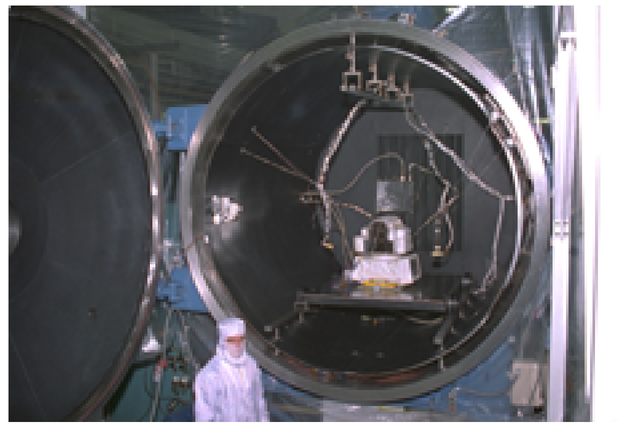
Pressure:	Capacitance manometer - Atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	126 thermocouple channels
Contamination monitor:	TQCM, coldfinger, residual gas analyzer

AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors. All portable solar systems can be used.

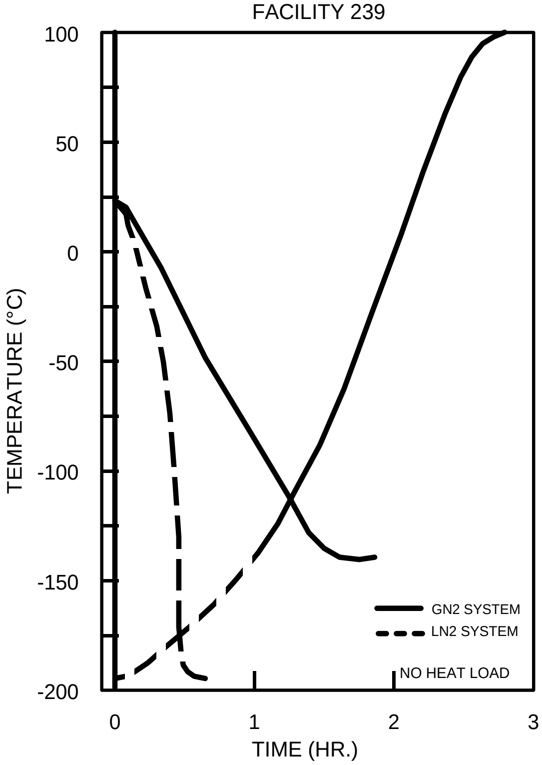


CART INTERFACE

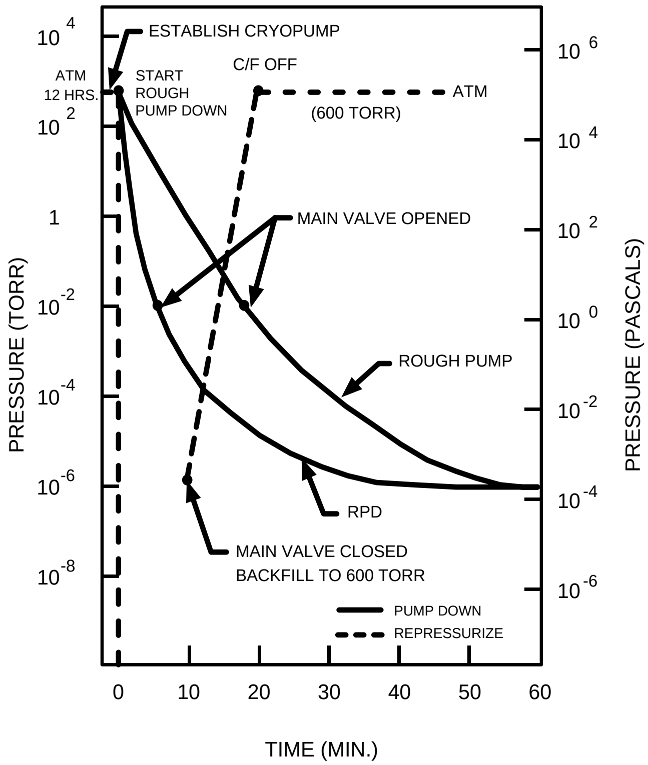
CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 239



CHAMBER VIEW



SHROUD TEMPERATURE
PERFORMANCE



PRESSURE PARAMETERS

A918.006

1.4.3.5 0.9M X 0.9M (3' X 3') DIFFUSION PUMPED VACUUM CHAMBER (FACILITY 240)

DESCRIPTION: This diffusion pumped facility is a horizontal loading thermal vacuum test chamber used for thermal vacuum testing and bakeout of test articles. The payload is mounted on a plate which is supported by rails welded to the chamber wall.

MODE OF OPERATION: After the test article is instrumented with thermocouples and placed in the chamber, ground support equipment cabling is connected through the penetration plates, and ambient functional checks are performed. Placing the test article on a baseplate or suspending it from the overhead rail are acceptable mounting methods. Chamber evacuation is provided by rotary piston mechanical pumps and an oil diffusion pump. A main valve allows test set up while the pumping system is being established.

PARAMETERS:

Test pressure:	<13.3 μpa (10^{-7} torr)
Shroud temperature:	-140°C to 110°C (-220°F to 230°F)
Chamber pumping speed:	1,600 lit /sec (3,400 cfm) @ 133 μpa (10^{-6} torr)
Evacuation time:	Atm to 133 μpa (10^{-6} torr) in 2 hours

PHYSICAL CHARACTERISTICS:

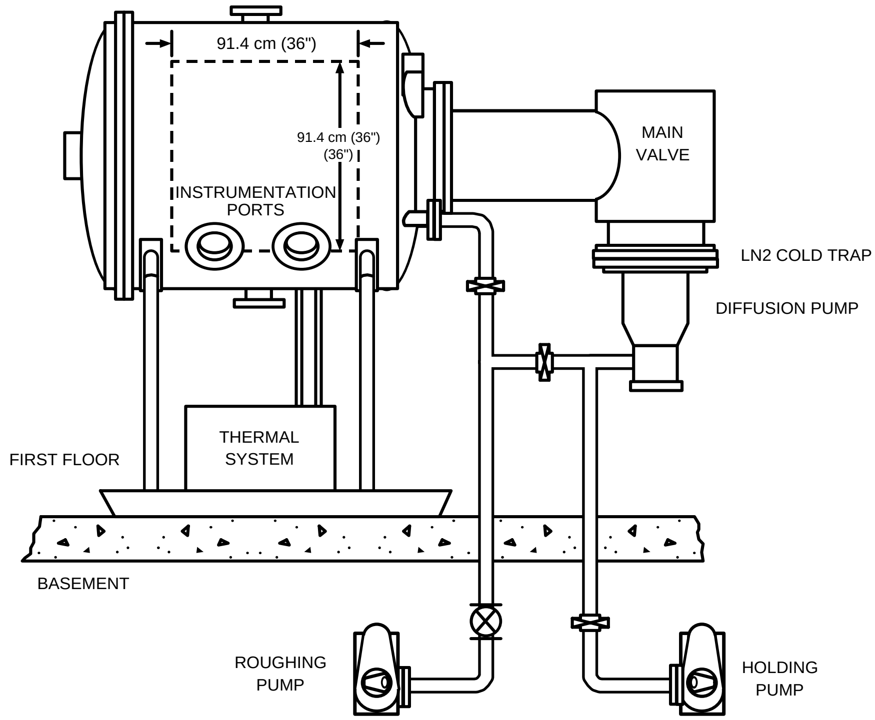
Test volume:	0.91m diameter x 0.91m L (3' x 3')
Std. electrical feedthroughs:	37-pin, 7-pin, 4-pin, RF

INTEGRAL INSTRUMENTATION:

Pressure:	Capacitance manometer - atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	18 thermocouple channels
Contamination:	TQCM, cold finger, residual gas analyzer

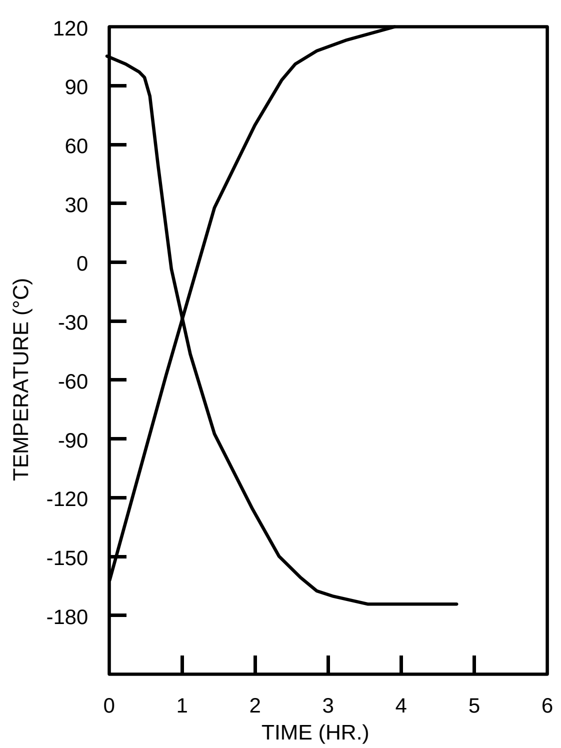
AUXILIARY EQUIPMENT: Portable thermal systems are available to control baseplates, the thermoelectric quartz crystal microbalance (TQCM), and contamination control mirrors.

3' X 3' CHAMBER (FACILITY 240)

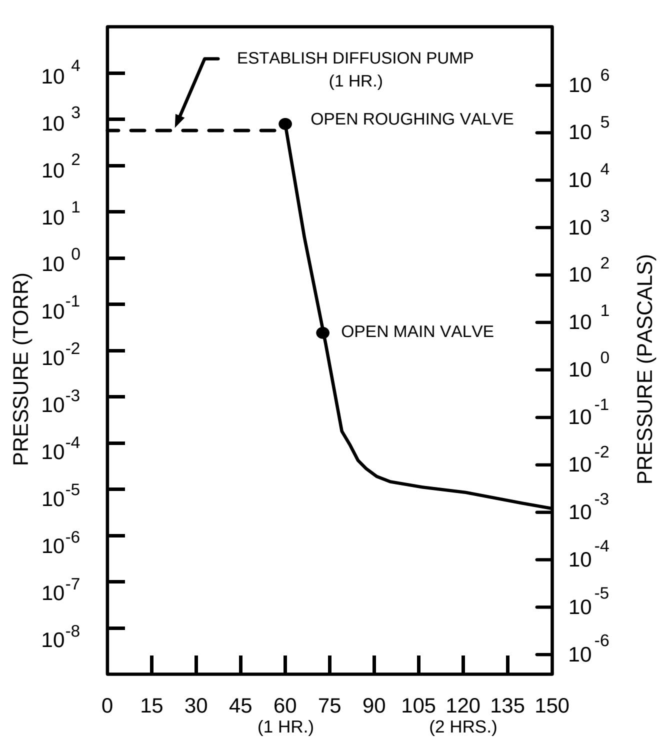


CHAMBER & VACUUM SYSTEM SCHEMATIC

FACILITY 240



SHROUD TEMPERATURE
PERFORMANCE



PRESSURE PARAMETERS

A918.007

1.4.3.6 0.9M X 0.9M (3' X 3') CRYOPUMPED VACUUM CHAMBER (FACILITY 241)

DESCRIPTION: This cryopumped facility is a horizontal loading thermal vacuum chamber used for thermal vacuum testing and bakeout of test articles. The payload is mounted on a plate which is supported by rails welded to the chamber wall.

MODE OF OPERATION: After the test article is instrumented with thermocouples and placed in the chamber, ground support equipment cabling is connected through the penetration plate, and ambient functional checks are performed. After roughing down the chamber with the rotary piston mechanical pump, ultimate pressure is achieved with the cryopump. A main valve allows test set up while the pumping system is being established.

PARAMETERS:

Test pressure:	<13.3 μpa (10^{-7} torr)
Shroud temperature:	-140°C to 110°C (-220°F to 230°F)
Chamber pumping speed:	1,500 lit /sec (3,200 cfm) @ 133 μpa (10^{-6} torr)
Evacuation time:	Atm to 13.3 pa (10^{-1} torr) in 5.5 minutes
	13.3 pa to 13.3 μpa (10^{-7} torr) in 2 hours

PHYSICAL CHARACTERISTICS:

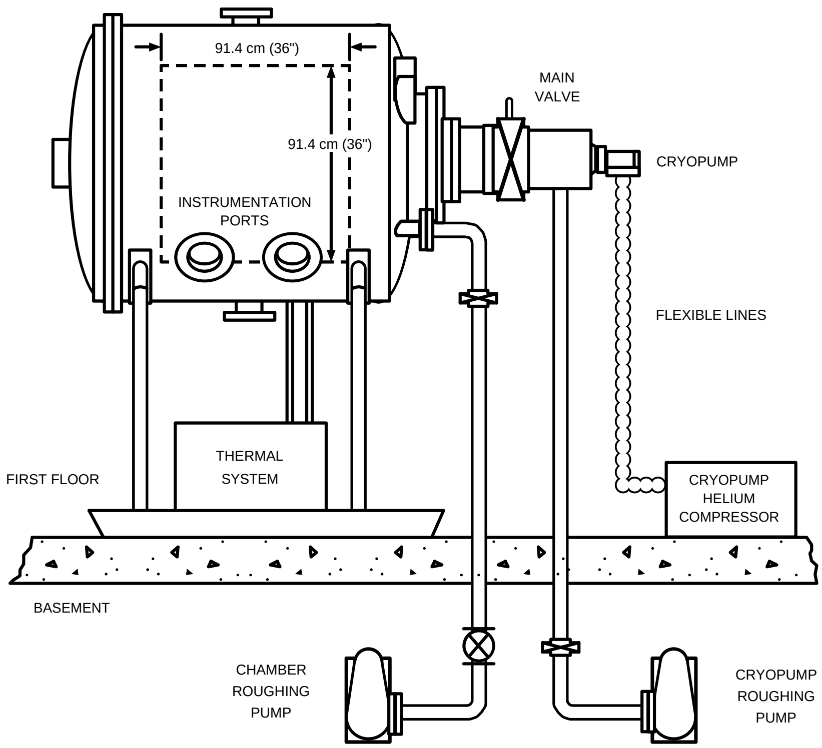
Test volume:	0.91m diameter x 0.91m L (3' x 3')
Std. electrical feedthroughs:	37-pin, 7-pin, 4-pin, RF

INTEGRAL INSTRUMENTATION:

Pressure:	Capacitance manometer - Atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	18 thermocouple channels
Contamination monitor:	TQCM, coldfinger, residual gas analyzer

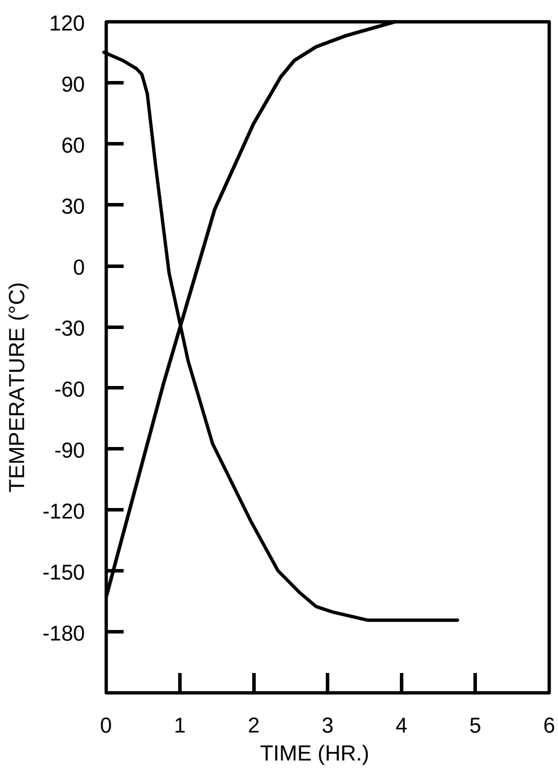
AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.

3' X 3' CHAMBER (FACILITY 241)

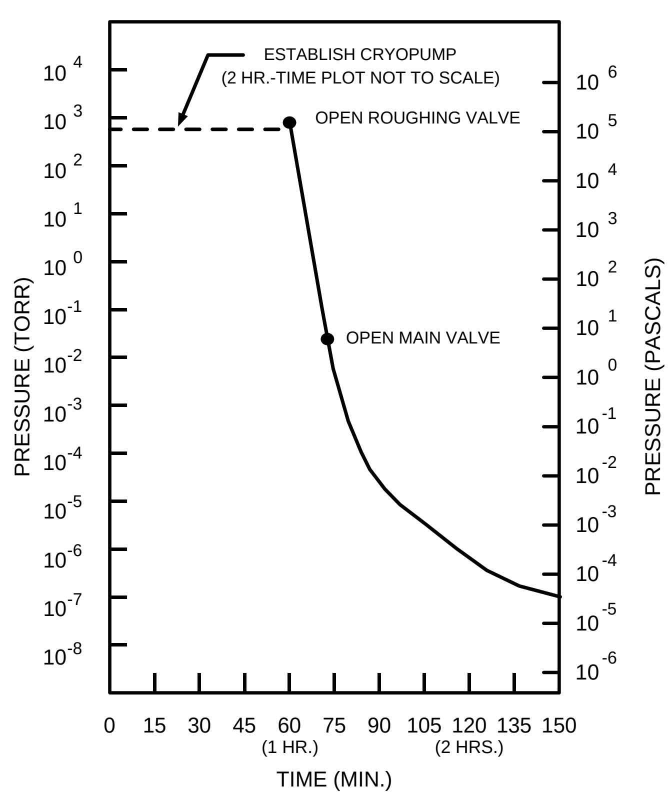


CHAMBER & VACUUM SYSTEM SCHEMATIC

FACILITY 241



SHROUD TEMPERATURE PERFORMANCE



PRESSURE PARAMETERS

A918.008

1.4.3.7 0.6M X 0.6M (2' X 2') VACUUM CHAMBERS (FACILITIES 243 AND 244)

DESCRIPTION: These diffusion pumped facilities are vertical, top-loading "belljar" test chambers used for thermal vacuum and thermal balance testing, and baking out test hardware. They are equipped with a viewport to accommodate an external solar simulator.

MODE OF OPERATION: The test article is mounted to a fixture suspended from the chamber lid. After the payload is instrumented with thermocouples, the lid is placed on the chamber. Ground support equipment cabling is connected through the penetration plate, and ambient functional checks are performed. For solar testing, it is normal to perform an alignment check with the external simulator prior to pump down.

Chamber evacuation is provided by rotary piston mechanical pumps and an oil diffusion pump. A sliding gate main valve allows test set up while the pumping system is being established.

PARAMETERS:

Test pressure:	<67 µpa (5 x 10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-140°C to 100°C (-220°F to 212°F)
LN_2 mode:	-190°C (-310°F)
Chamber pumping speed:	300 lit/sec (640 cfm) @ 133 µpa (10^{-6} torr)

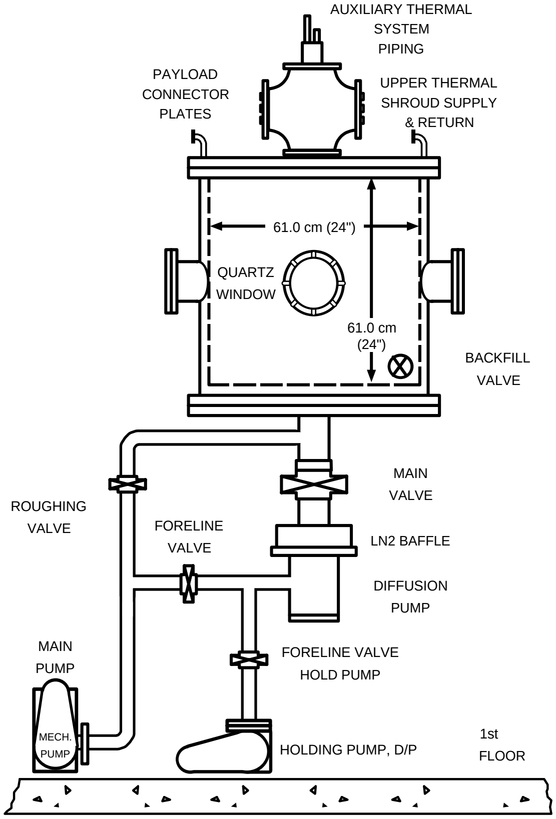
PHYSICAL CHARACTERISTICS:

Test volume:	0.61m dia x 0.61m H (2' x 2')
Hoist capacity:	454 Kg (1,000 lb)
Viewport dimensions:	19cm dia (7.5") quartz window
Std. electrical feedthroughs:	37-pin, 7-pin, 4-pin, RF

INTEGRAL INSTRUMENTATION:

Pressure:	Capacitance manometer - atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	18 thermocouple channels
Contamination:	TQCM, cold finger, residual gas analyzer

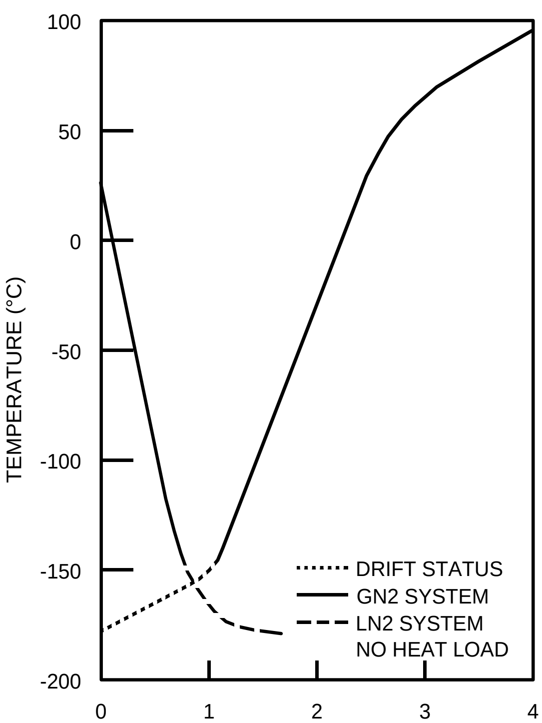
AUXILIARY EQUIPMENT: Portable thermal systems are available to control baseplates, the thermoelectric quartz crystal microbalance (TQCM), and contamination control mirrors. Also, a portable solar simulator can be used to illuminate the payloads.



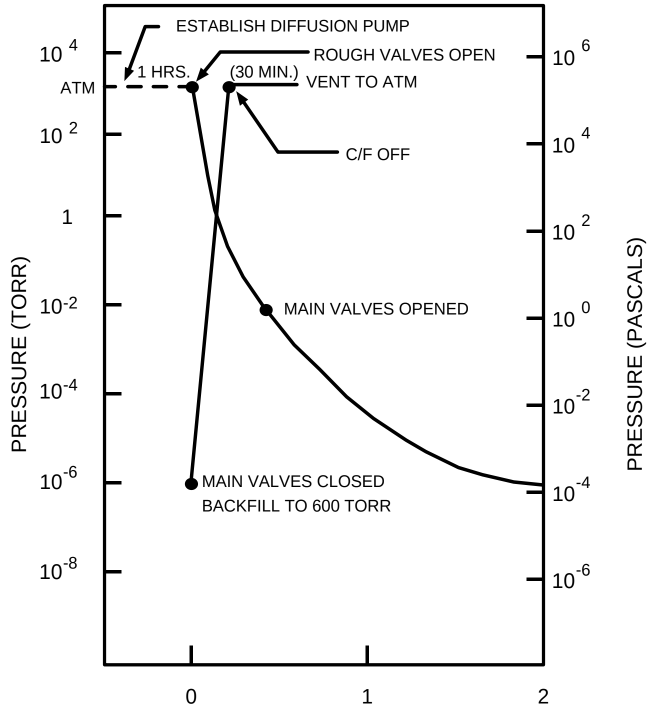
CHAMBER & VACUUM SYSTEM SCHEMATIC

CHAMBER VIEW

FACILITY 243 & 244



SHROUD TEMPERATURE PERFORMANCE



PRESSURE PARAMETERS

A918.009

1.4.3.8 0.9M X 1.2M (3' X 4') CRYOPUMPED VACUUM CHAMBER (FACILITY 281)

DESCRIPTION: This cryopumped facility is a horizontal loading thermal vacuum chamber used for thermal vacuum testing and baking out test articles. The payload is mounted on a plate which is attached to rails in the chamber.

MODE OF OPERATION: After the test article is instrumented and installed in the chamber, it is connected to the ground support equipment and data acquisition system via electrical feedthroughs. After roughing down the chamber with the mechanical pump, ultimate pressure is achieved with a cryopump. A main valve allows test set up while the pumping system is being established.

PARAMETERS:

Test pressure:	<13.3 µpa (10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-150°C to 150°C (-238°F to 302°F)
Chamber pumping speed:	1,500 lit/sec (3,200 cfm) @ 133 µpa (10^{-6} torr)
Evacuation time:	Atm to 13.3 pa (10^{-1} torr) in 5.5 minutes
	13.3 pa to 213 µpa (1.6 x 10^{-6} torr) in 2 hours

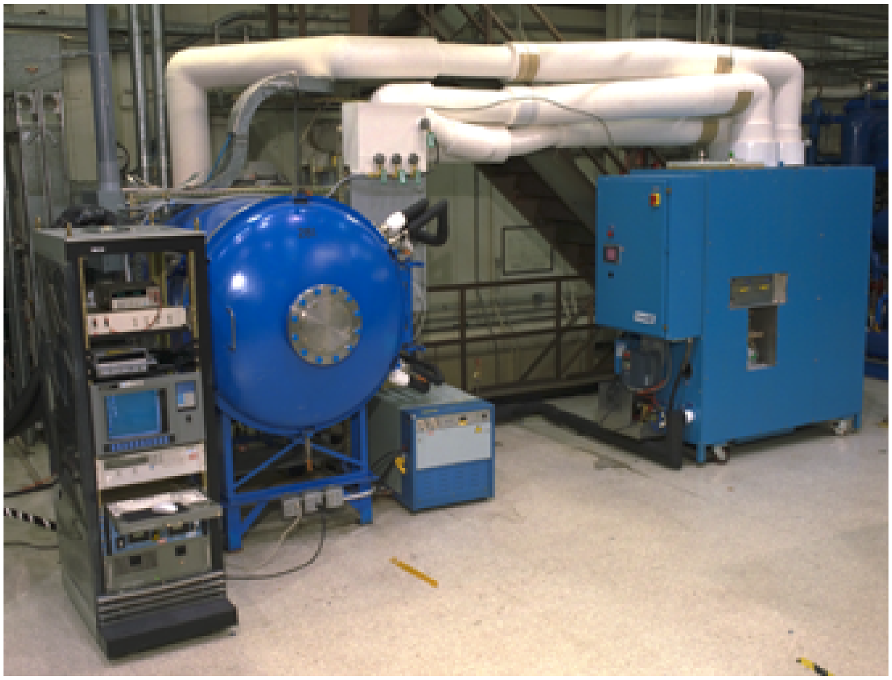
PHYSICAL CHARACTERISTICS:

Test volume:	0.91m diameter x 1.22m L (3' x 4')
Payload support:	Plate on support rails
Std. electrical feedthroughs:	37-pin, 7-pin, 4-pin, RF

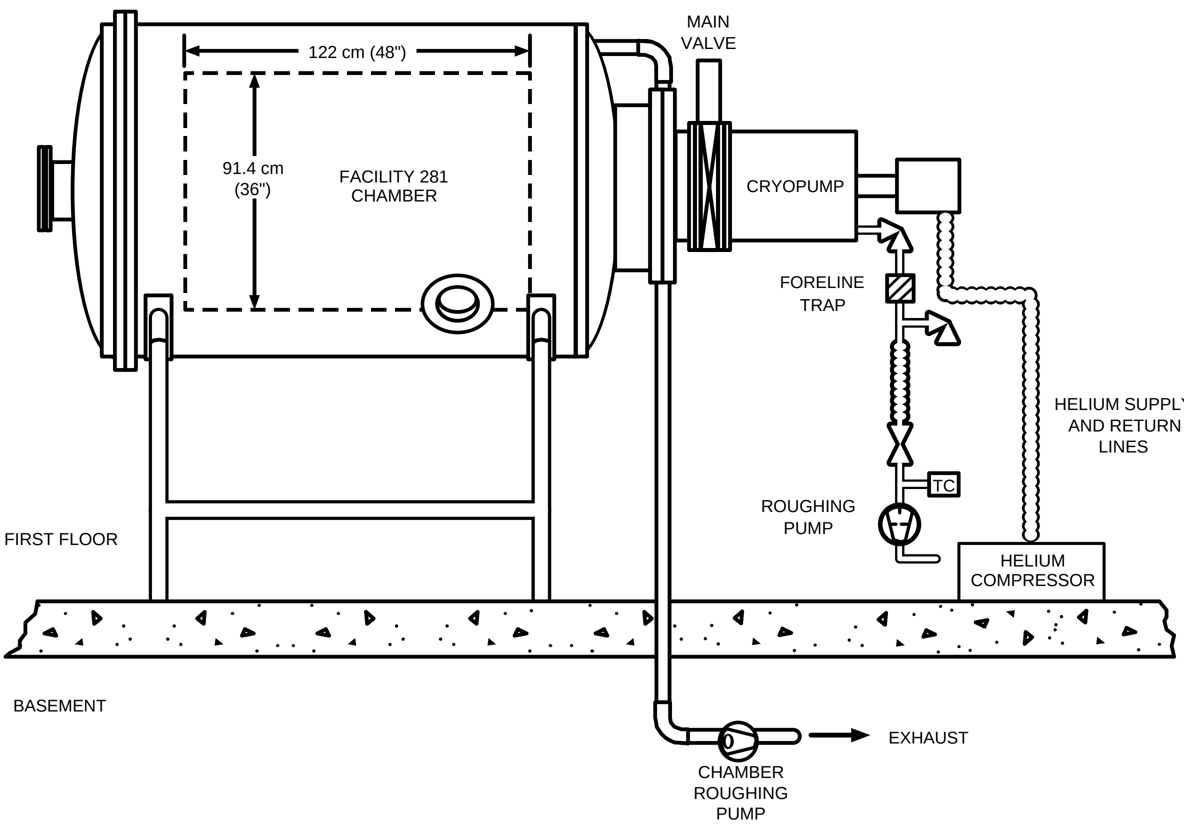
INTEGRAL INSTRUMENTATION:

Pressure:	T/C gauge - atm to 0.13 pa (10^{-3} torr)
	Capacitance manometer - Atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	18 thermocouple channels
Contamination monitor:	TQCM, coldfinger, residual gas analyzer

AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.



CHAMBER VIEW



CHAMBER & VACUUM SYSTEM SCHEMATIC

FACILITY 281

A918.010

1.4.3.9 8.2M X 12.2M (27' X 40') CRYOPUMPED VACUUM CHAMBER (FACILITY 290)

DESCRIPTION: This cryopumped facility is a vertical, very large Space Environment Simulation (SES) test chamber capable of achieving ultra low pressure and a wide range of thermal conditions. Test articles are loaded through the top of the chamber using the Building 10 crane. Personnel entry is through a side opening access port. Two small viewports are located on the chamber side at different elevations. The chamber is used for thermal vacuum and thermal balance testing, and baking out very large test articles. A Class 10,000 clean anteroom provides personnel and small payload access to the chamber.

MODE OF OPERATION: The test article is loaded onto the payload table or internal fixturing with the chamber dome rolled back. Often, special fixturing is required. An external HEPA-filtered clean air supply provides fresh air to the chamber during pre-test activities. Entry to instrument the payload with thermocouples, connect ground support equipment cabling, and install hardware is through a cleanroom airshower at the personnel door. Wearing of clean garments is required. Scaffolding may be erected to provide access to the payload. An area adjacent to the main facility control console is reserved for the experimenter's ground support equipment.

Chamber evacuation is provided by eight rotary piston mechanical pumps with Roots blowers, and eight cryopumps. A turbomolecular pump is available to pump the lighter gasses to achieve ultra low pressures. Thermal control is provided by an aluminum tube-in-sheet cylindrical shroud with both liquid nitrogen and gaseous nitrogen operational modes. The dome and bottom shrouds are also connected to the thermal skids. Resistance heater arrays, with external power supplies or gaseous nitrogen panels, are available for special thermal requirements. A thermoelectric quartz crystal microbalance (TQCM) and residual gas analyzer (RGA) provide both quantitative and qualitative monitoring of molecular contamination and gaseous constituents within the chamber. Closed circuit television coverage is available for monitoring the test article.

HELIUM SKID: A 1.2 kilowatt helium refrigeration system is piped to 2.54cm (1") VCR fittings inside the chamber that may be connected to manifolds providing the capability of achieving 20˚Kelvin on those surfaces. This is enough cooling energy to cool, and then maintain, panels in fixtures large enough to encompass entire payloads.

PARAMETERS:

Test pressure:	13.3 μpa (10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-130°C to 100°C (-202°F to 212°F)
LN_2 mode:	-180°C (-292°F)
Chamber pumping speed:	
8 cryopumps:	2.4×10^5 lit/sec (5.1×10^5 cfm) @ 133 μpa (10^{-6} torr)
Turbomolecular pump:	6,000 lit/sec (12,700 cfm) @ 133 μpa (10^{-6} torr)

PHYSICAL CHARACTERISTICS:

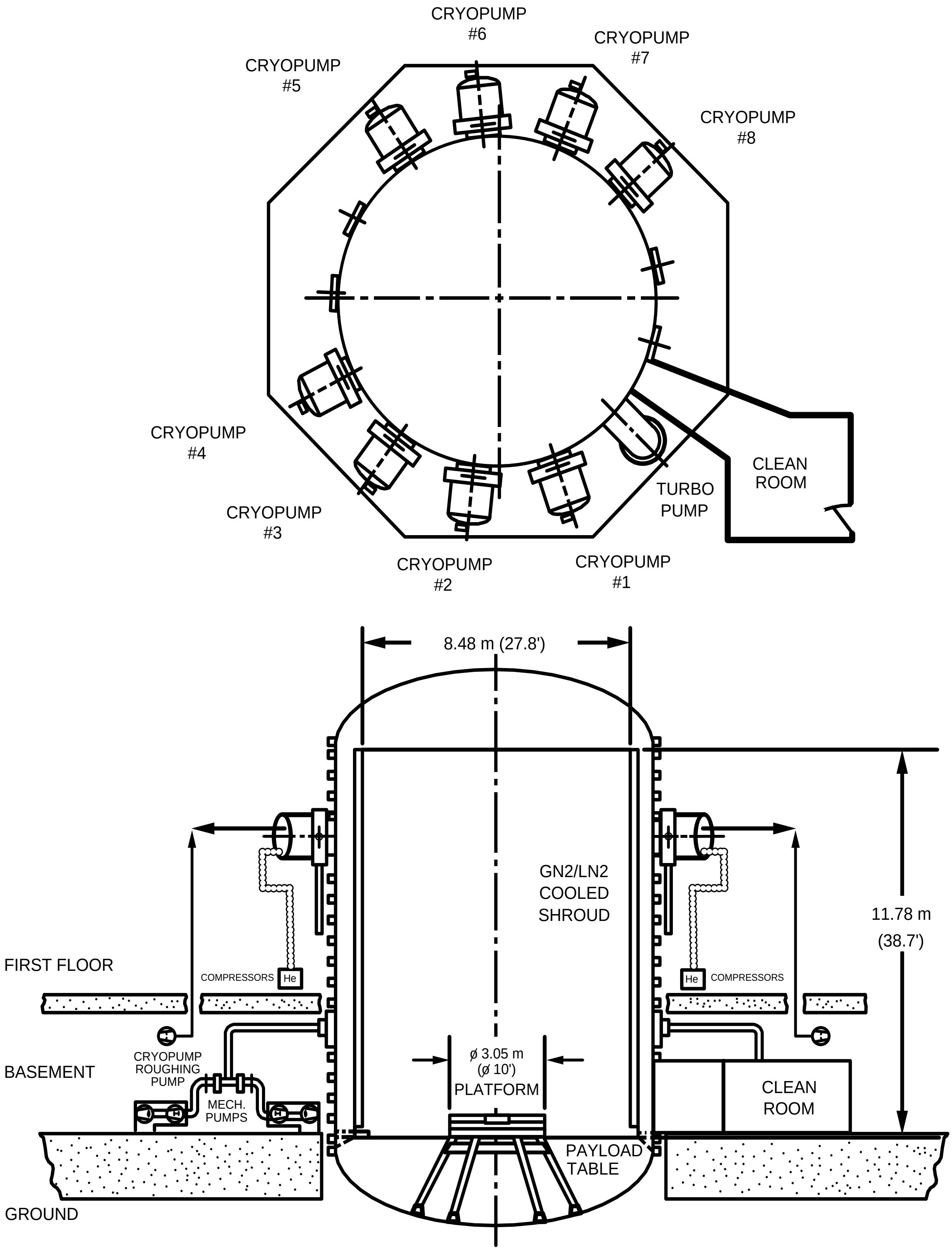
Test volume:	8.23m diameter x 12.19m H (27' x 40')
Payload support:	9,072 Kg (20,000 lb)
Removable floor:	11,794 Kg (26,000 lb)
Viewports:	30 cm (12") two each
Std. electrical feedthroughs:	37-pin, 7-pin, 4-pin, RF

INTEGRAL INSTRUMENTATION:

Pressure:	Capacitance manometer (2) - Atm to 0.13 pa (10^{-3} torr)
	Ion gauge (4) - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	600 channels of thermocouples, thermistors, or voltage signals
Contamination monitor:	TQCM, coldfinger, residual gas analyzer
TQCM frequencies:	4 - 15 MHz; 2 - 10 MHz

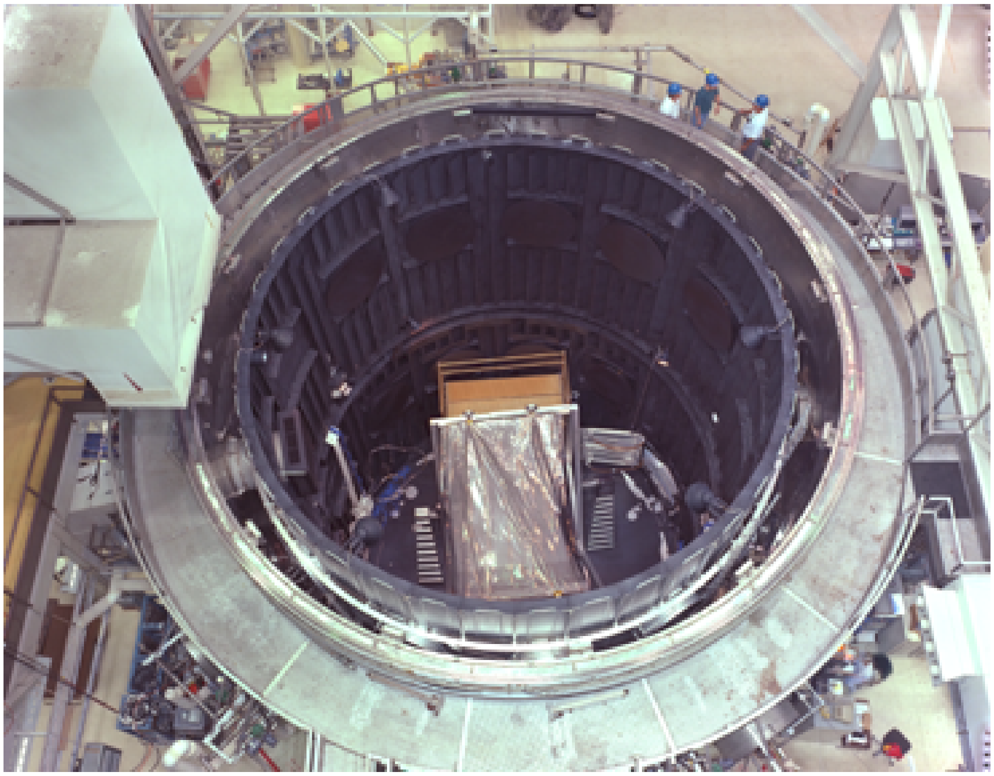
AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.

FACILITY 290 CONTROL MIMIC PANEL

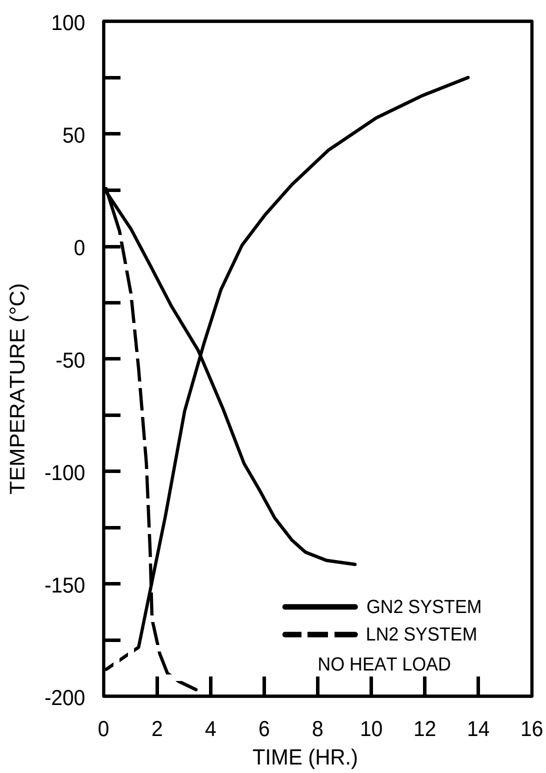


CHAMBER AND VACUUM SYSTEM SCHEMATIC
FACILITY 290

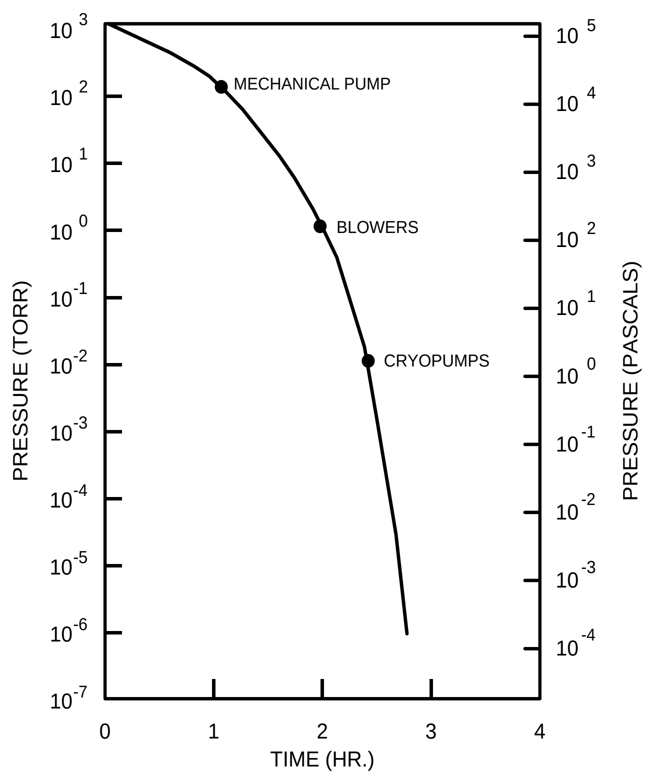
A918.011



CHAMBER VIEW



SHROUD TEMPERATURE PERFORMANCE



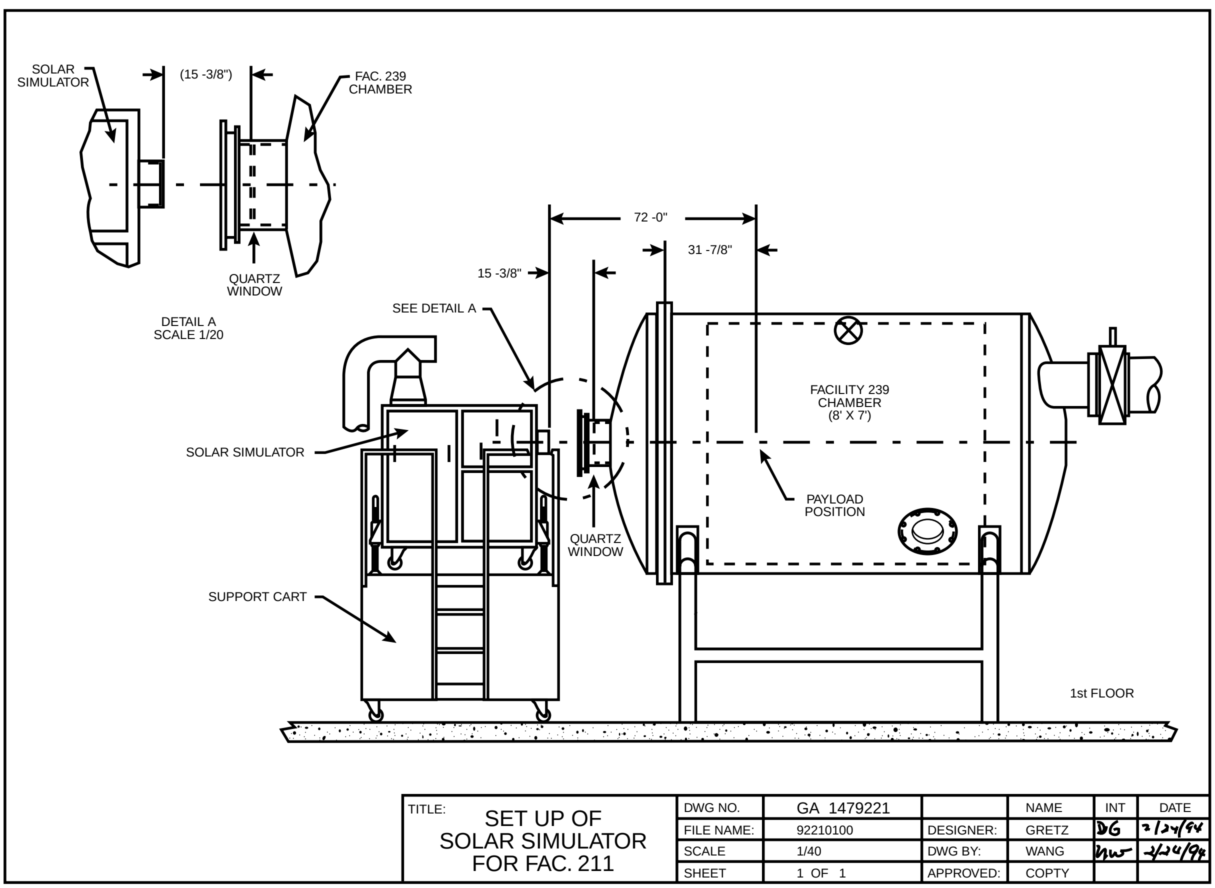
FAC. 290 PUMPDOWN

A918.012

1.4.4 SOLAR SIMULATORS, PORTABLE

DESCRIPTION: A portable solar simulator is designed to simulate the sun's effects on flight hardware. In particular, it can simulate the rapid thermal changes that an orbiting satellite would experience as it cycles in and out of the sun's illumination and Earth's shadow. The simulator contains a solar lamp, projection optics, power supply, cooling system, and controls necessary to project a beam onto a target plane.

MODE OF OPERATION: The simulator is set up externally to a thermal vacuum chamber so that its beam can project through a quartz window onto the payload target plane. The intensity is adjusted to the desired level, and the uniformity of the beam at the target plane is measured before the payload is installed inside the chamber. After the payload is installed, the lamp is aligned at the quartz window at the required distance from the target plane. The lamp is ignited and the payload illuminated per the test procedure. Typical specifications include the intensity measured in solar constants, beam width and distance from target, number of "ON/OFF" cycles, and duration of each cycle.



A2521.006

SOLAR SIMULATOR SET UP AT CHAMBER

1.4.4.1 61CM (24") - 1 S.C. SOLAR SIMULATOR (FACILITY 211)

DESCRIPTION: This portable solar simulator projects a divergent beam. The unit is mounted on a castered platform to provide alignment with the windows of the medium-sized thermal vacuum chambers. The power supply and controls are incorporated in a separate castered console.

MODE OF OPERATION: The intensity is adjusted to the desired level, and uniformity of the beam at the target plane is measured before the test article is installed in the facility. The lamp is then aligned at the quartz window at the required distance from the target plane. The lamp is ignited and the payload illuminated in accordance with the test procedure.

PARAMETERS:

Beam size:	61cm (24") across flats	Intensity:	90 to 270 mw/cm^2 (0.16 in^2); 0.6 to 1.0 S.C.
Target plane:	191cm (75") from exit optics	Uniformity:	± 10% max of average intensity
Subtense angle:	7° half angle	Spectrum:	Filtered to air mass zero solar spectrum

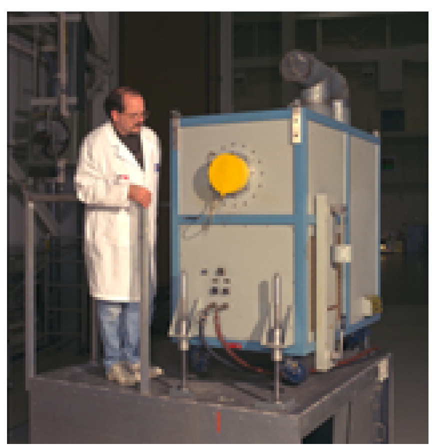
PHYSICAL CHARACTERISTICS:

Source:	One 6.5 Kw xenon arc lamp	Utility requirement:	
Lamphouse:	76cm x 137cm x 122cm (30" x 54" x 48")	Power:	480V, 60Hz, 3 phase, 35amp 110V, 60Hz, 1 phase, 25amp
Control console:	76cm x 76cm x 183cm (30" x 30" x 72")		
Platform:	173cm x 76cm x 127cm (68" x 30" x 50")	Cooling water:	15°C to 30°C (59°F to 86°F) 11 to 19 lit/min (3 to 5 gal/min)
Exhaust fan:	8.5 m^3/min (300 ft^3/min)		

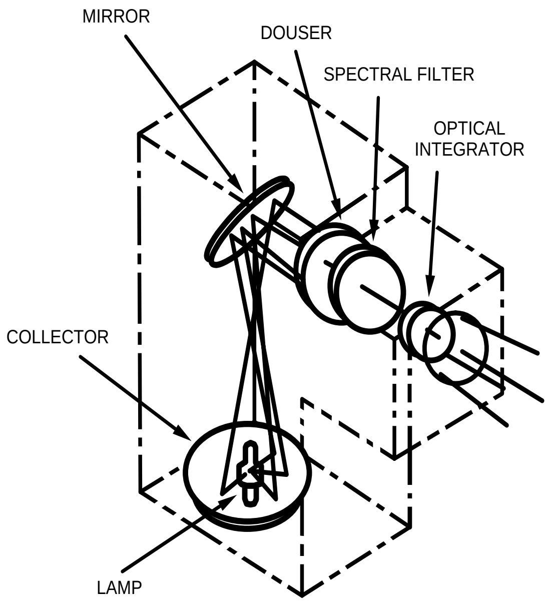
INTEGRAL INSTRUMENTATION:

Lamp voltage:	0-150 VDC	Lamp intensity:	0-200 mw/cm^2 (0.16 in^2)
Lamp current:	0-200 amp DC	System alarms:	Klaxon and lights

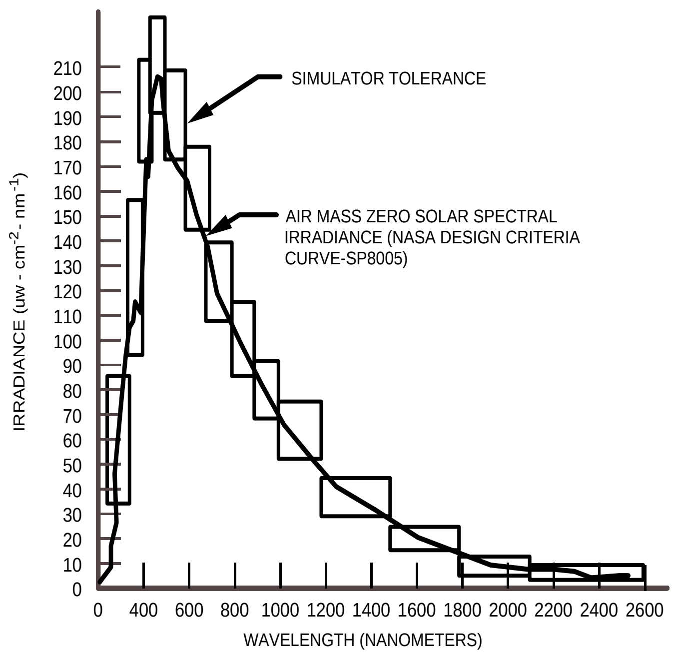
POWER SUPPLY



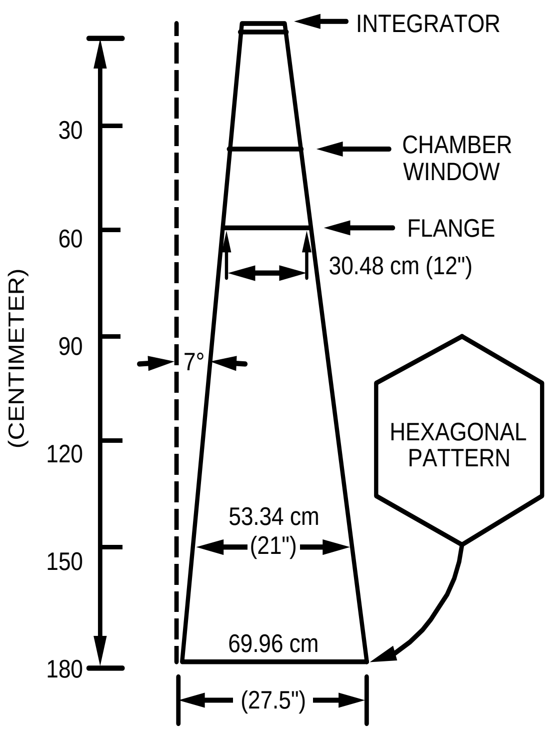
SOURCE MODULE



OPTICAL SCHEMATIC



SOLAR SIMULATOR SPECTRUM



BEAM SIZE OF SOLAR SIMULATOR

SPECTRAL BAND	NOMINAL ENERGY LEVEL (MW/CM^2)	DEVIATION (±%)
.25-.35	6.25	40
.35-.40	6.30	25
.40-.45	9.64	10
.45-.50	10.60	10
.50-.60	19.09	10
.60-.70	16.24	10
.70-.80	12.78	10
.80-.90	10.20	15
.90-1.0	8.07	15
1.0-1.2	12.30	20
1.2-1.5	11.25	20
1.5-1.8	6.10	20
1.8-2.2	4.50	30
2.2-2.5	1.99	30

SOLAR SIMULATOR SPECTRAL IRRADIANCE

A918.013

1.4.4.2 33CM (13") - 1 S.C. SOLAR SIMULATOR (FACILITY 213)

DESCRIPTION: This portable solar simulator incorporates the lamp, projection optics, power supply, and controls in a single castered cabinet. Power driven screw jacks at each corner permit raising the cabinet 61cm (24") to align the simulator with the chamber window.

MODE OF OPERATION: The intensity is adjusted to the desired level, and uniformity of the beam at the target plane is measured. After the payload is installed in the test facility, the lamp is aligned at the window at the required distance from the target plane. The lamp is ignited and the payload illuminated in accordance with the test procedure.

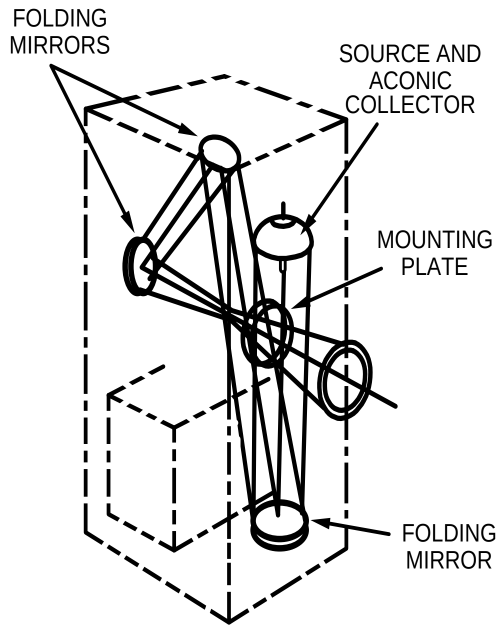
PARAMETERS:

Beam size:	33cm (13") across flats
Target plane:	55cm to 244cm (22" to 96") from exit optics
Subtense angle:	7° half angle
Intensity:	81 to 162 mw/cm^2 (0.16 in^2)
Spectrum:	Filtered to air mass zero solar spectrum
Uniformity:	± 5% max of average intensity as measured with a 1cm x 2cm (0.4" x 0.8") solar cell

PHYSICAL CHARACTERISTICS:

Source:	One 2.5Kw xenon arc lamp
Size:	58cm x 58cm x 213cm (23" x 23" x 84")
Power required:	480V, 60 Hz, 3 phase, 15 amp

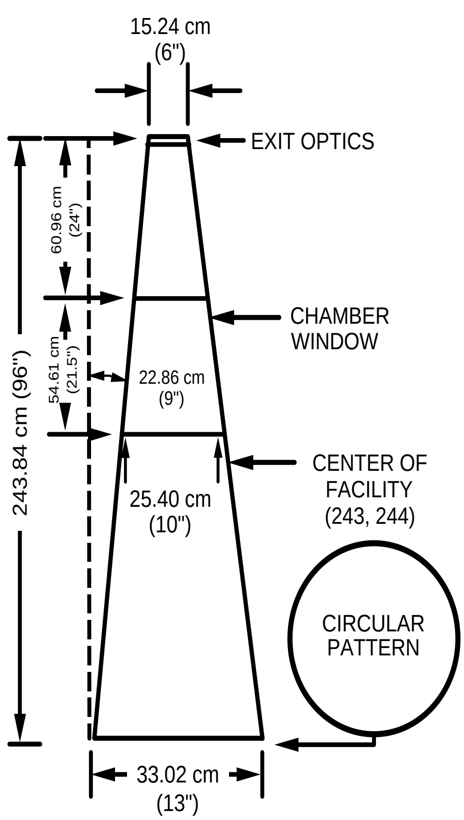
33CM SOLAR SIMULATOR



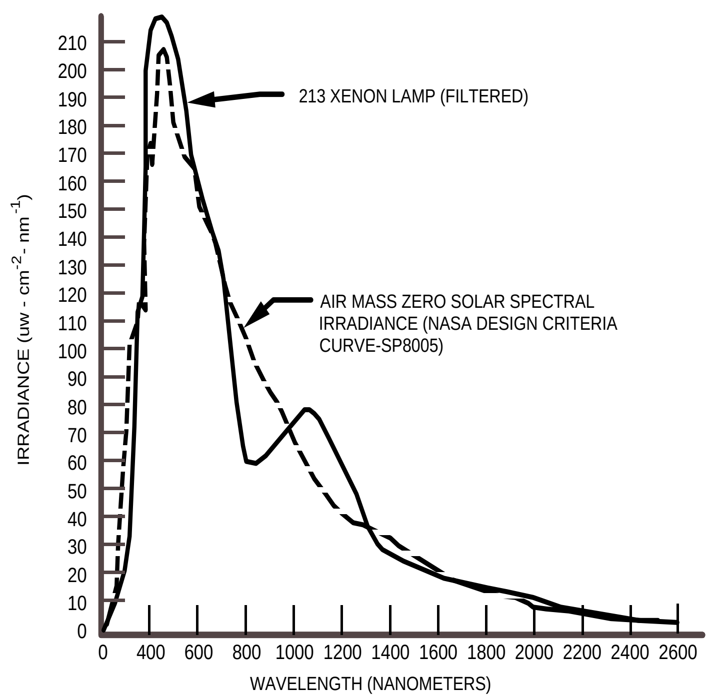
OPTICAL SCHEMATIC

SPECTRAL BAND	NOMINAL ENERGY LEVEL (MW/CM^2)	DEVIATION (±%)
.25-.35	7.80	40
.35-.40	11.80	20
.40-.45	19.00	10
.45-.50	21.80	10
.50-.60	19.00	10
.60-.70	15.00	10
.70-.80	11.50	10
.80-.90	6.00	15
.90-1.0	6.50	15
1.0-1.2	8.00	20
1.2-1.5	3.20	20
1.5-1.8	2.00	20
1.8-2.2	1.20	30
2.2-2.5	0.70	30

SOLAR SIMULATOR SPECTRAL IRRADIANCE



BEAM SIZE OF SOLAR SIMULATOR



SPECTRAL FILTERING EFFECTIVENESS

A918.014

1.4.5 THERMAL VACUUM DATA ACQUISITION FACILITY

DESCRIPTION: This facility is a client/server Windows NT network application operating over a local area network (LAN.) It is designed to measure, display, and store data such as temperature, chamber pressure, thermoelectric quartz crystal microbalance (TQCM) frequencies, voltages, and other chamber and payload data.

MODE OF OPERATION: Data is acquired by the Supervisory Control and Data Acquisition (SCADA) computer every two minutes and recorded in the thermal vacuum Oracle database located on the server. Data stations located throughout Labs 7 and 10 can view this data through an Ethernet TCP/IP connection. The Thermal/Vacuum Data System (TVDS) graphical user interface (GUI) displays the data in tabular and graphical formats.

The number and location of payload thermocouples are determined by the experimenter/thermal engineer. Facility thermocouples are strategically placed to provide a full representation of all chamber shrouds. The different operating parameters (temperature, pressure, TQCM frequencies, and rate of TQCM change) can be viewed simultaneously in tabular format or graphical plot. All measuring devices have alarm limits that allow for facility and payload control.

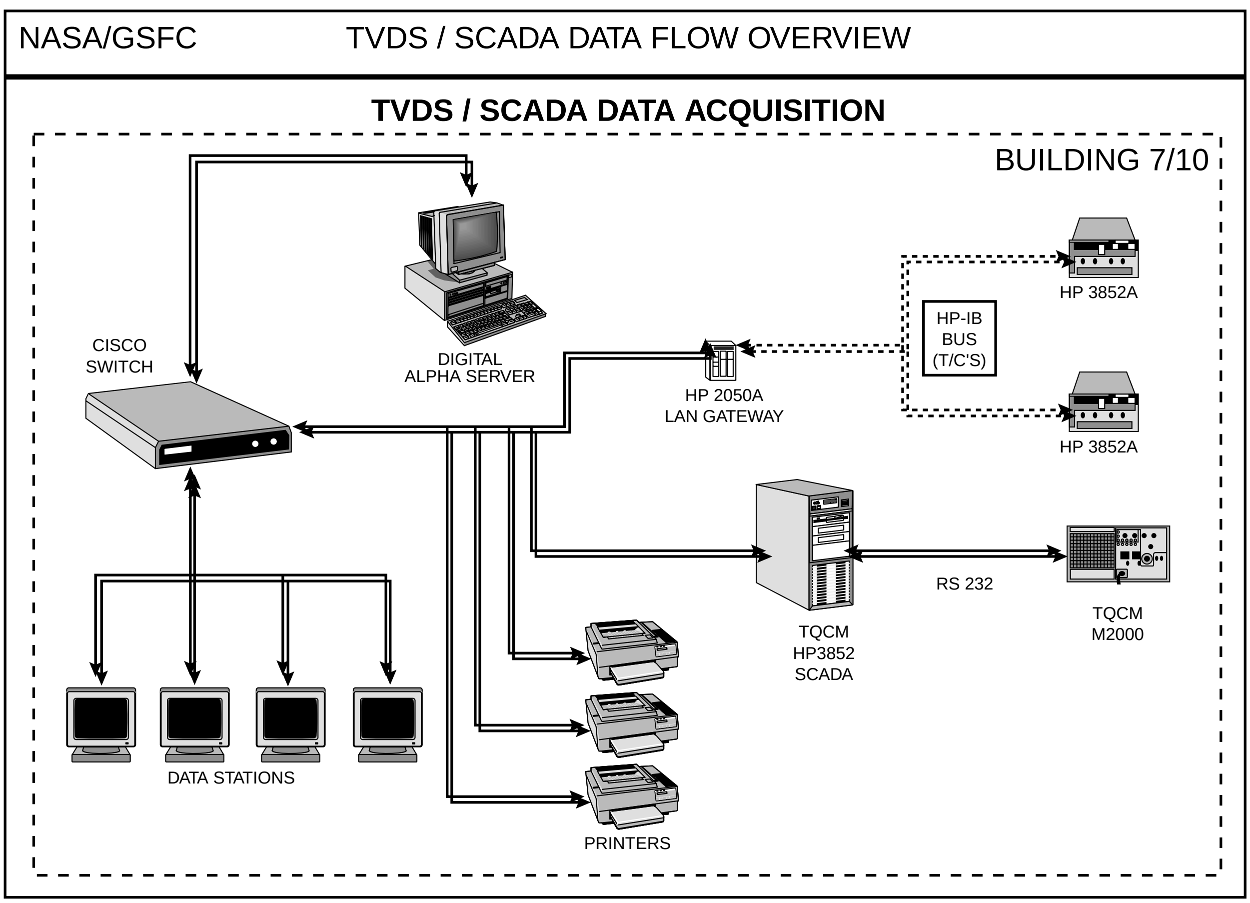
All recorded data and data station configurations are stored in an Oracle database on a Digital Alpha server. An uninterruptible power supply prevents the loss of data in case of a power outage. Data is backed up daily and stored on magnetic tape.

SOFTWARE FEATURES: The TVDS application runs on each data station and can be customized by the operator or experimenter. Any facility that is active (under test) can be viewed on any data station. Security is implemented by controlling each user's level of access to each system with a password.

Operators have the ability to create, start and stop tests, enable/disable measuring devices, and edit alarm limits, averages and gradients. Display options include unlimited tabular displays, unlimited graphical plot displays, multiple color schemes, scale-able plots, and copying displays from other data stations. All tabular and plot displays can be printed to a LAN printer.

A separate utility provides access to recorded data in ASCII format. This utility can run during a test to record data to a file that can then be accessed by a third party software. This utility is also useful for gathering data to a floppy or network location after a test's completion.

THERMAL VACUUM DATA ACQUISITION AREA



A2521.005

THERMAL VACUUM DATA ACQUISITION SYSTEM SCHEMATIC

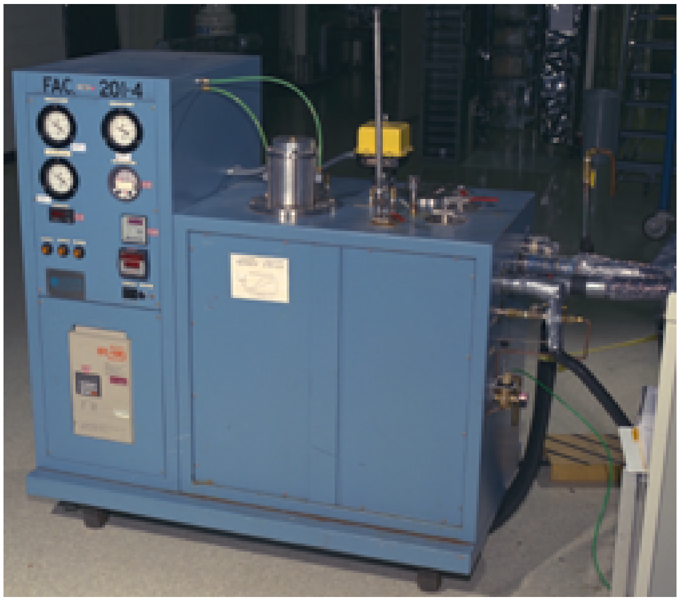
1.4.6 THERMAL CONDITIONING UNITS

DESCRIPTION: The following thermal conditioning units are portable and available for use at each thermal vacuum facility as needed. They are designed to produce and maintain a wide range of temperatures. The heat transfer medium is GN_2 for all units. Typical applications for these units include independent thermal control of test articles and contamination monitoring devices such as mirrors and TQCMs. Chamber penetrations are configured to accommodate the thermal conditioning units.

Facility No.	Temp Range	Heating Cap. (watt)	Cooling Cap. (watt)	Size (H x W xD)	MFR	Notes
201	-140 to 140˚ C (-220 to 284˚ F)	1,400	1,000	1.8m x 0.97m x 1.7m (5.9' x 3.2' x 5.6')	CVI	
205	-100 to 100˚ C (-148 to 212˚ F)	500	500	0.89m x 0.51m x 0.51m (2.9' x 1.7' x 1.7')	Slack	1
207	-100 to 100˚ C (-148 to 212˚ F)	300	300	0.38m x 0.38m x 0.38m (1.3' x 1.3' x 1.3')	Slack	1
230	-150 to 150˚ C (-238 to 302˚ F)	12,000	10,000	2.1m x 0.81m x 2.1m (6.8' x 2.7' x 6.8')	DynaVac	

Note 1: Thermal capacities at nominal 10°C (18°F) gradient

FACILITY 205



FACILITY 201

1.4.7 ELECTRICAL HEATER CONTROLLER (FACILITY 242)

DESCRIPTION: The electrical heater controller rack is a standard 48cm (19") electronic console that contains direct current power supplies, power distribution, and a microprocessor-based control panel. Heater circuits can be controlled individually at continuously variable temperatures between -100 and +100°C (-148 and +212°F). Power available for heater circuits is 5.4 Kw maximum.

MODE OF OPERATION: Each temperature control panel can control sixteen heater circuit zones. The microprocessor-based panel uses a platinum resistance temperature detector to feed back real time temperature data. The panel uses a proportional plus integral plus derivative (PID) rate characteristic to control a solid state relay. The time-proportioning control circuitry cycles the solid state relay to control the power to the heater. All adjustments are available from the front panel and can be locked against tampering. Each heater zone is alarmed.

PARAMETERS:

Temperature:	-100 to +100°C (-148 to +212°F)
Heater zones:	16 channels
Heater power:	5.4 Kw maximum

PHYSICAL CHARACTERISTICS:

Portable unit:	2.08m H x 0.61m W x 0.61m D (6.82' x 2' x 2')

HEATER CONTROLLER RACK

1.4.8 AUTOMATED ELECTRIC HEATER CONTROLLER (FACILITY 315)

DESCRIPTION: This system can control up to twelve heater circuits, each of which can be in temperature controlled or constant power mode, as desired. Four of the circuits can be in zero-Q. The rack contains twelve direct current power supplies, a programmable logic controller (PLC), a touch screen operator interface, and a Modbus Plus communication port. The system uses the proportional plus integral plus derivative (PID) control strategy.

MODE OF OPERATION: The heater system can be operated at the touch screen or remotely via Modbus Plus from a desktop computer. For each circuit, the user enters the mode, set point, temperature limit, heater current limit, and the heater resistance. The PLC then controls the amount of continuous (i.e., not pulsed) current to the heater to achieve the desired temperature or power level. Temperatures and power levels (in any mode) are stored in the thermal vacuum data system.

PARAMETERS:

Temperature:	-200 to +200°C (-328 to +392°F)
Heater zones:	12 channels
Heater power:	600 watts per channel (0-150 volts DC @ 0-4 amperes)
Modes:	Temperature controlled, constant power, zero-Q
Temperature sensors:	Type T thermocouples

PHYSICAL CHARACTERISTICS:

Portable unit:	2.06m H x 0.56m W x 0.76m D (6.75' x 1.8' x 2.5')

AUTOMATED HEATER CONTROLLER

1.4.9 RAPID PUMPDOWN SYSTEM (FACILITY 208)

DESCRIPTION: This high-speed vacuum pumpdown system is comprised of two rotary piston pumps manifolded in parallel to a chamber exhaust line. Two 2.1m x 2.4m (7' x 8') thermal vacuum chambers (one diffusion pumped, one cryopumped) are manifolded in parallel to the exhaust line providing rapid pumpdown. There is a foreline valve at the inlet of each pump, and a shut-off valve at each chamber. The pumps and valves are located in the basement and operated from a remote console.

MODE OF OPERATION: Each pump is started, and its ultimate pressure is verified to be less than 2.66 pascal (2 x 10^{-2} torr). The foreline valve and the valve at the required chamber are opened. When test pressure is achieved, the chamber valve is closed. The foreline valves are closed and the pumps are secured.

PARAMETERS:

Ultimate pressure:	1.33 pa (10^{-2} torr)
Pump down time:	Either chamber - atm to 2.66 pa (2 x 10^{-2} torr) in 5 min.
Pump speed:	22m^3/min (780 ft^3/min) each pump

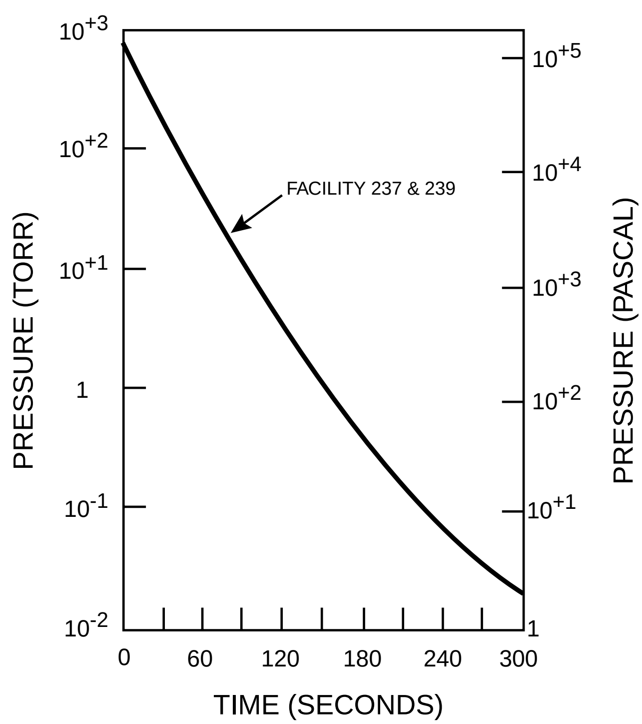
PHYSICAL CHARACTERISTICS:

Foreline size:	25cm (10") diameter
Chamber manifold:	31cm (12") diameter

INTEGRAL INSTRUMENTATION:

Pump foreline pressure:	T/C gauge for atm to 0.13 pa (10^{-3} torr)

RAPID PUMPDOWN SYSTEM



PRESSURE PROFILE

1.4.10 CONTAMINATION MONITORING
1.4.10.1 RESIDUAL GAS ANALYZER (RGA)

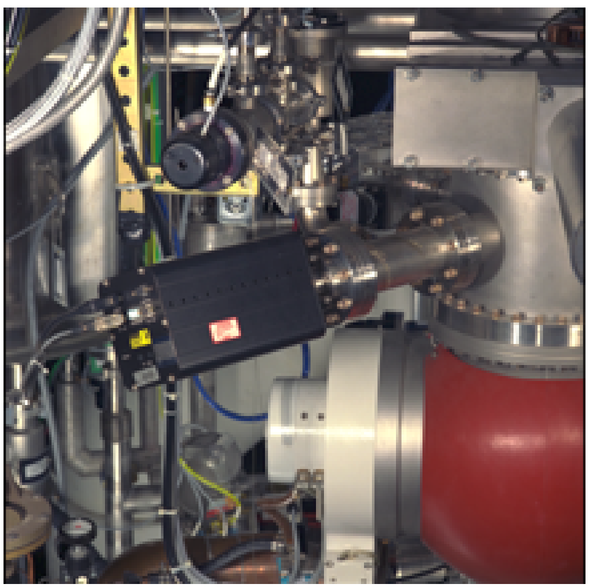
DESCRIPTION: The residual gas analyzer is used to measure the partial pressures of ionized molecules over a mass range of 1 to 200 atomic mass units (AMU). Using a combined RF and electrostatic field formed by two metal rods, the RGA scans the mass range and detects the partial pressures of each element or compound fraction.

MODE OF OPERATION: The RGA probe is located in the thermal vacuum facility and is oriented to maximize the detection of the outgassing species. After the facility pressure reaches 13.3 mpa (10^{-4} torr), the instrument may be activated. An alternate technique is to use the micro-sampling valve at high chamber pressure. Monitoring and recording of the vacuum environment is via a display meter and printer.

PARAMETERS:

Make & Model	Faraday Cup	Electron Multiplier	AMU Range	Max. Operating Pressure	Min. Detectable Partial Pressure
MKS PPT-1A-100FC	Yes	No	1-100	13.3 mpa (1.0×10^{-4} torr)	1.33×10^{-9} pa (10×10^{-12} torr)
Leybold C100F	Yes	No	1-100	13.3 mpa (1.0×10^{-4} torr)	6.7×10^{-9} pa (50×10^{-12} torr)
MKS PPT-200EM	Yes	Yes	1-200	13.3 mpa (1.0×10^{-4} torr)	6.7×10^{-12} pa (50×10^{-14} torr)

Note: Two auxiliary RGA manifolds are available, with appropriate valves, that provide sampling of chamber gasses when chamber pressure is between 13.3 mpa (10^{-4} torr) and atmosphere.



RGA INSTALLED ON CHAMBER

1.4.10.2 THERMOELECTRIC QUARTZ CRYSTAL MICROBALANCE

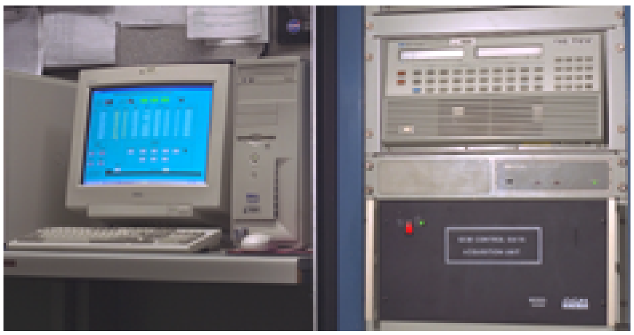
DESCRIPTION: The thermoelectric quartz crystal microbalance (TQCM) and M-2000 control unit system measures and records condensable masses which deposit on a piezoelectric crystal. Extreme accuracy is obtained by comparing the exposed measurement crystal to a matched encapsulated reference crystal located in the same TQCM head. A computer controlled thermoelectric pump provides a high degree of crystal temperature control, which is vital for accurate frequency measurement. Two TQCM sensing units may be used, 10 MHz or 15 MHz. All relevant data is sent from the M-2000 control unit and the PC control station to the data acquisition and reduction facility.

MODE OF OPERATION: One or more TQCM sensing units are installed in a thermal vacuum chamber. The chamber is pumped down to a test pressure of 1.33 mpa (10^{-5} torr) or less, at which point the TQCM is turned on and set for the appropriate operating temperature. As the payload outgasses and materials condense on the TQCM sensing crystal, the crystal frequency increases directly proportional to the amount of payload outgassing.

PARAMETERS:

Mass sensitivity:	4.43 x 10^{-9} g/cm^2-Hz (1.01 x 10^{-9} oz/in^2-Hz) for the 10 MHz unit
	1.97 x 10^{-9} g/cm^2-Hz (0.45 x 10^{-9} oz/in^2-Hz) for the 15 MHz unit
Crystal temperature:	-50 to +100°C, ± 0.1°C (-58 to +212°F, ± 0.18°F)
Sensor unit size:	5cm (2") diameter x 25.5cm (10") L with heat sink lines

INTEGRAL INSTRUMENTATION: The instrument consists of a TQCM sensor head unit, M-2000 multichannel control unit, SCADA station, and heat sink temperature control system.



TQCM COMPUTER CONTROL AND ACQUISITION UNIT

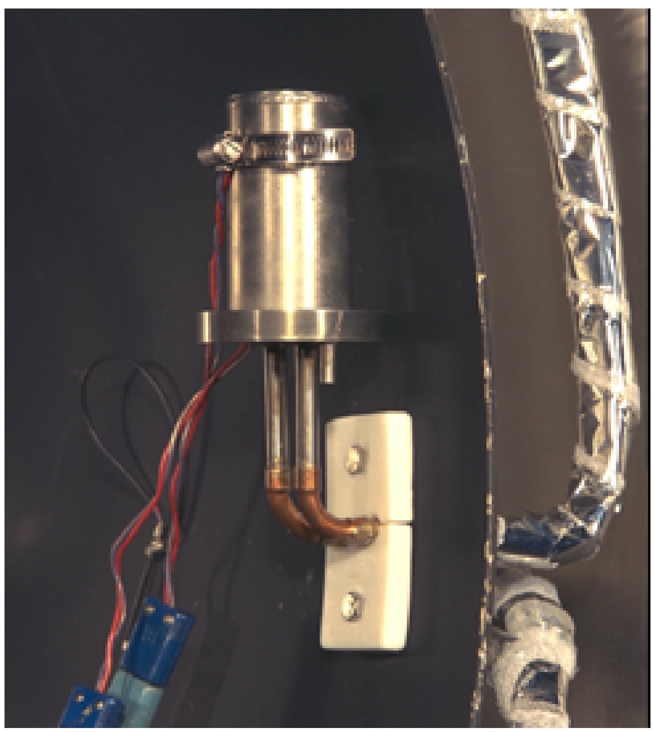
1.4.10.3 COLD FINGER (C/F)

DESCRIPTION: Cold fingers are small stainless steel cylinders which are mounted in the test volume of each thermal vacuum chamber. Condensable vapors are collected by the cold finger and analyzed after the test. In some cases, a large cold plate is used to collect the condensable materials. The cold finger is maintained at LN_2 temperature during test and until the chamber is backfilled to 80 Kpa (600 torr).

MODE OF OPERATION: The cold finger is thoroughly cleaned before the test. After the thermal vacuum test, the cold finger is warmed and again rinsed with isopropyl alcohol. The rinse sample is collected in a clean bottle and sent to the Materials Assurance Branch for quantitative and qualitative analyses.

PARAMETERS:

Size:	5cm (2") diameter x 7.6cm H (3")
Surface area:	142cm^2 (22 in^2) nominal
Temperature:	-196°C (-321°F)



C/F INSTALLED INSIDE CHAMBER

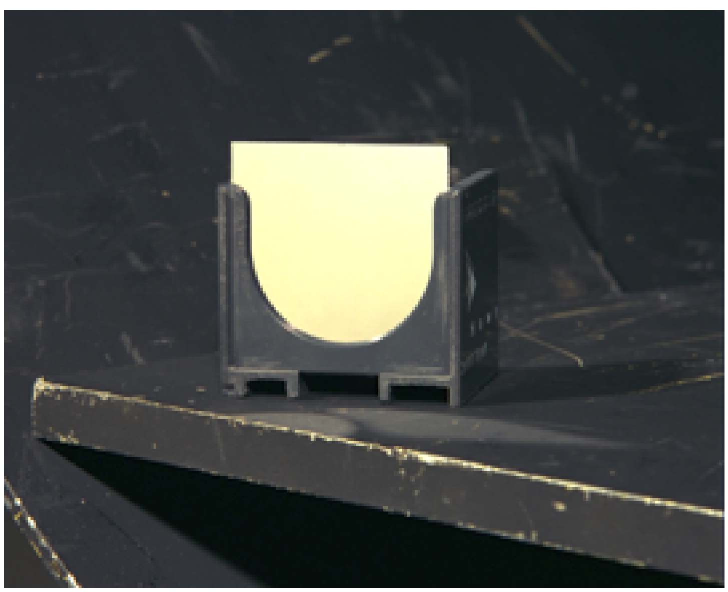
1.4.10.4 CONTAMINATION CONTROL MIRROR

DESCRIPTION: These aluminum coated mirrors are used primarily to collect outgassed materials in the thermal vacuum chambers; however, they may be placed anywhere to collect condensable matter. To determine the quantity of material on the mirror, reflective ultraviolet measurements are made prior to test, and then compared to post test measurements for a loss of reflectivity.

MODE OF OPERATION: The mirror is placed in the thermal vacuum chamber (or other environment) and allowed to remain in that location for the duration of the test. In most cases, the mirror's temperature follows the thermal vacuum chamber temperature profile; however, the mirror's temperature can be controlled if desired. For large accretions (greater than 10% change in reflectivity) the mirror is sent to the Materials Assurance Branch for chemical analysis of the non-volatile residue.

PARAMETERS:

Temperature:	-190 to +100°C (-310 to +212°F)
Measurement error:	± 2%
Measurement wavelength:	1216Å, 1608Å, and 2000Å
Mirror size:	5cm x 5cm (2" x 2"), coated on one side
Coating:	Al - 600 to 800Å thick
Over coating:	MgFl - 250Å thick



MIRROR INSTALLED INSIDE CHAMBER

2.0 INTEGRATION SERVICES AND FACILITIES

The Environmental Test and Integration Branch provides trained personnel and facilities necessary to support integration of flight hardware ranging from sub-assemblies to fully-configured flight spacecraft. Integration services and facilities include mechanical integration support, electrical cable harness development, thermal blanket development, contamination control support, and cleanroom facilities. The Environmental Test and Integration Branch's functions include the following integration disciplines:

Mechanical Integration:	Maintenance and operation of cleanrooms Electrical and mechanical integration Handling of spacecraft Functional checks of spacecraft hardware Field support at launch sites and remote facilities
Thermal Blanket Facility:	Thermal blanket template design Thermal blanket fabrication Thermal blanket installation Launch site closeout and support
Electrical Cable Harness Facility:	Cable harness fabrication Continuity and insulation resistance testing Cable harness routing design Cable harness installation and test
Cleanrooms and Contamination Control Support:	10K (M5.5) cleanrooms and tents Particle and hydrocarbon monitoring Witness plate monitoring and analysis Cleanroom garments and supplies Precision cleaning

2.1 MECHANICAL INTEGRATION

INTRODUCTION

The Center possesses both the facilities and personnel necessary for mechanically integrating spaceflight hardware, including instruments, ground support equipment, and complete spacecraft. This integration effort is provided from the inception of the program through launch and recovery. Integration is performed either in the cleanrooms or in the general laboratories, as appropriate. Contamination-sensitive flight hardware and systems are integrated in the cleanrooms, while non-sensitive hardware is completed in the general integration facilities. A more detailed explanation of the Center's integration capabilities follows.

2.1.1 HANDLING OF SPACECRAFT

Typical spacecraft handling tasks include preparation of procedures, use of hydrasets, crane operations, proof testing of lifting devices and handling carts, and fabrication of lifting cables. The Center has extensive facilities, hardware, and trained personnel for both routine and quick reaction handling tasks. Logistics for shipping, receiving, and packaging are also provided at GSFC and other offsite locations.

2.1.2 FABRICATION SUPPORT

Frequently, quick reaction machining operations need to be performed so that spacecraft integration tasks will remain on schedule. Trained personnel, using precision equipment and facilities, are available to modify or fabricate critical components and hardware as required.

2.1.3 ASSEMBLY

Both Center and project-supplied hardware is used by the integration group in the assembly of flight systems. Precision assembly tools, measuring instruments, and trained personnel are used to ensure precise alignment and installation of flight hardware. Precision optical transit squares, interferometers, surface tables, inclinometers, electronic levels, height gauges, and helio-precision measuring tools are some of the instruments used for this effort.

2.1.4 FUNCTIONAL CHECKS OF SPACECRAFT MECHANISMS

Center personnel perform weight, moment of inertia, center of gravity, and product of inertia measurements on flight hardware. Functional checks of hinged doors, solar panel deployment mechanisms, payload ejection systems, and boom deployments are routinely conducted in accordance with the designer’s and experimenter’s specifications. Integration personnel also work closely with electronics personnel when installing electronic packages and routing electrical harnesses.

2.1.5 FIELD SUPPORT

When required, Center personnel are available for field support at contractor sites, launch sites, and other NASA installations. Typical operations performed during field support tasks are covered above.

2.2 THERMAL BLANKET FACILITY

DESCRIPTION: The thermal blanket facility is equipped to provide all aspects of design, layout, fabrication, and installation of multi-layer insulation (MLI) for flight spacecraft, instrumentation, mock-ups, and test fixtures. Consultant services are provided to other NASA centers and aerospace vendors.

MODE OF OPERATION: To meet thermal design requirements, each blanket is custom built. Materials can be baked out in thermal vacuum chambers before fabrication begins. Afterward, the completed blanket can be baked. Metalized and non-metalized thin films (such as Mylar, Kapton and Teflon), dacron netting, special adhesives and tape, fluoroglas fabric (Beta cloth), and a variety of fasteners are stocked and used in the fabrication and installation process. Flight blankets consisting of metalized films are electrically grounded to the spacecraft during installation to avoid build up of static charge. Existing blankets are also modified, refurbished, and repaired.

PHYSICAL CHARACTERISTICS:

7 each fabrication tables (two in controlled, dust-free enclosures)
Hand held vacuums, one air table, and three mobile material carts
Two medium/heavy weight industrial sewing machines
Storage for completed MLI and templates

ADDITIONAL NOTES: Bulk blankets generally do not exceed 1.22m x 3.35m (4' x 11'). Installation or construction of MLI can occur directly on hardware in the facility if cleanliness requirements are not stringent and size does not exceed 2.13m L x 1.68m W x 1.98m H (7' x 5.5' x 6.5'). Blanket patterning, modification, and installation often occur in other areas of integration or testing, in contamination-controlled areas, and offsite.

BLANKETS ON PAYLOAD

2.3 CABLE HARNESS FACILITY

DESCRIPTION: The cable harness facility is equipped to provide all aspects of design, procurement of materials, fabrication, and checkout of electrical cable harnesses for non-flight and flight systems. The Electrical Systems Support Group maintains and operates this facility. The group provides consultant services to flight projects regarding the use of materials, fabrication methods, and certifications required to withstand environmental testing and the rigors of space.

MODE OF OPERATION: To meet flight system electrical design requirements, each cable harness is custom built to specifications provided by the customer. Cable harnesses may contain a wide variety of soldered or crimped connections and may also contain fiber optic terminations. Polymerics are applied, as specified, to protect the final cable harness assembly. The wires, connectors, backshells, and braiding material can be baked out in thermal vacuum chambers before fabrication begins. After fabrication, the completed harnesses can be baked out as an assembly, and are then routed, installed, and integrated to the flight hardware and/or spacecraft. Materials are procured per the requirements of the NASA Preferred Parts List (PPL) MIL-STD-975 and the GSFC Incoming Inspection and Test System (GPG 4520.2A). Workstations are set up with equipment to minimize electrostatic discharge. The group can modify or repair existing cable harnesses. End-to-end verification tests include checks of continuity, resistance, and dielectric strength of materials. Qualified fabricators are certified to the following standards:

- Soldered Electrical Connections NASA-STD-8739.3
- GSFC Crimp, Cable and Harnessing NASA-STD-8739.4
- Fiber Optic Terminations NASA-STD-8739.5
- Electrostatic Discharge Control NASA-STD-8739.7
- Polymeric Application NAS5300.4 (3J-1)

PHYSICAL CHARACTERISTICS:

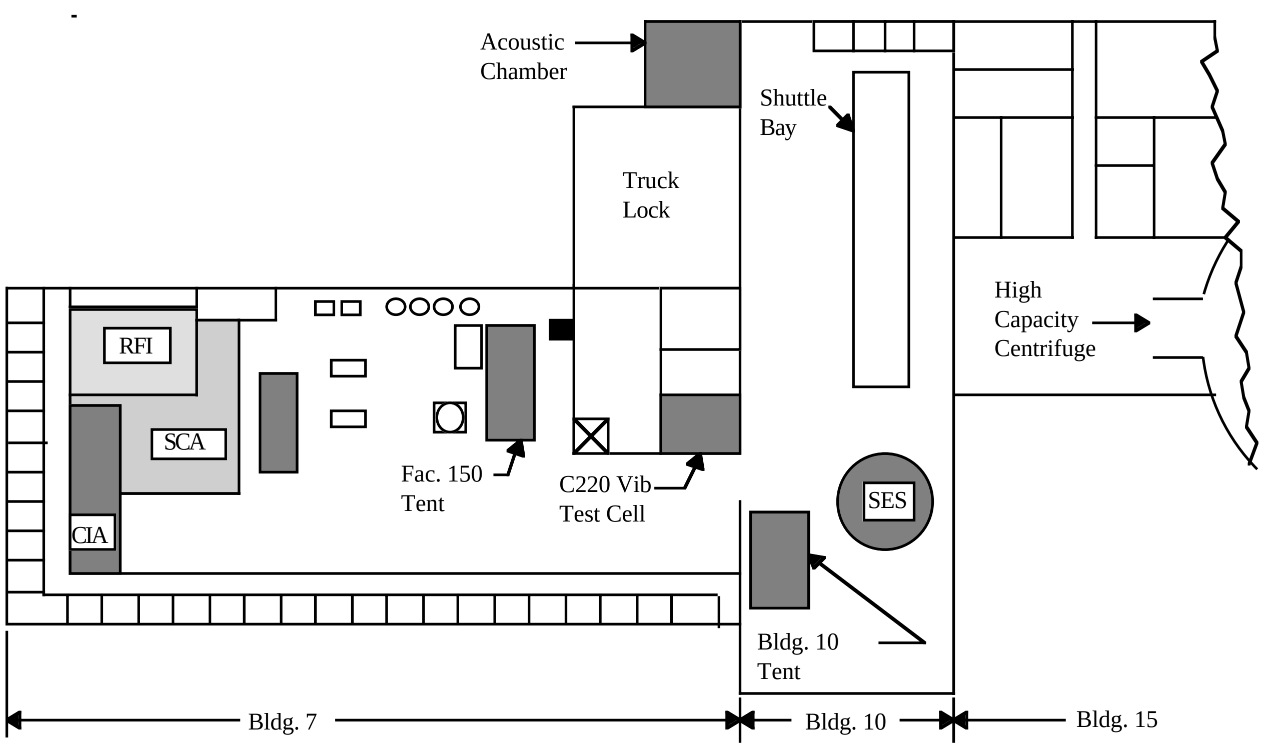
6 each fabrication workstations with electrostatic discharge control
Temperature-controlled calibated soldering stations
Calibrated crimpers and wire strippers
1500-volt megohmmeter and 4-lead digital voltmeter
Pin retention testers, crimp quality pull testers, and torque wrenches
Locked room and cage for secure storage of flight materials

ADDITIONAL NOTES: Cable harnesses can be fabricated at any location and in any lengths desired. This includes working in clean rooms and around flight hardware, while maintaining cleanliness control standards.

2.4 CLEANROOMS

DESCRIPTION: Cleanrooms are designed and operated to maintain a classification of air cleanliness by introducing air into the room, tent, or bench with conditioned recirculatory or direct ambient air systems through a series of high efficiency (HEPA) air filters. The filtered air is maintained at specified velocities in a unidirectional flow pattern that causes contaminants generated within the facility to be carried away in the direction of the moving air stream.

MODE OF OPERATION: Cleanrooms are monitored on a periodic basis to verify that the classification of the facility remains within specification. Cleaning is performed on a predetermined or "as required" schedule based on classification monitoring results. Used cleanroom garments are continuously removed from the change rooms and replaced with fresh packaged garments. Project personnel are present inside the cleanrooms during test activity to insure that proper cleanroom procedures are followed.



BUILDINGS 7, 10, & 15 CLEAN ROOM LOCATIONS

2.4.1 SPACECRAFT CHECKOUT AREA (SCA)

SIZE	17m L x 11m W x 10m H (56' x 36' x 33')
SOUTH WALL FILTER BANK	5,664 m^3/min (200,000 ft^3/min) - horizontal flow
AIR VELOCITY	30m/min (100'/min), minimum
TEMPERATURE	21 ± 3° C (70 ± 5° F)
RELATIVE HUMIDITY	48 ± 4%
ENTRANCE (HARDWARE)	Rollup door: 5.9m W x 6.0m H (19.4' x 19.7')
CLEANLINESS	Class 10,000 (M5.5)
OTHER SERVICES	electrical, compressed dry nitrogen, under-floor cable tray system, telephone and intercom, outlets for central vacuum
OTHER PARAMETERS	The walls and exposed steel are painted with an epoxy paint to keep particle generation to a minimum. The concrete floor has a polyurethane coating.

2.4.2 RFI SHIELDED ROOM

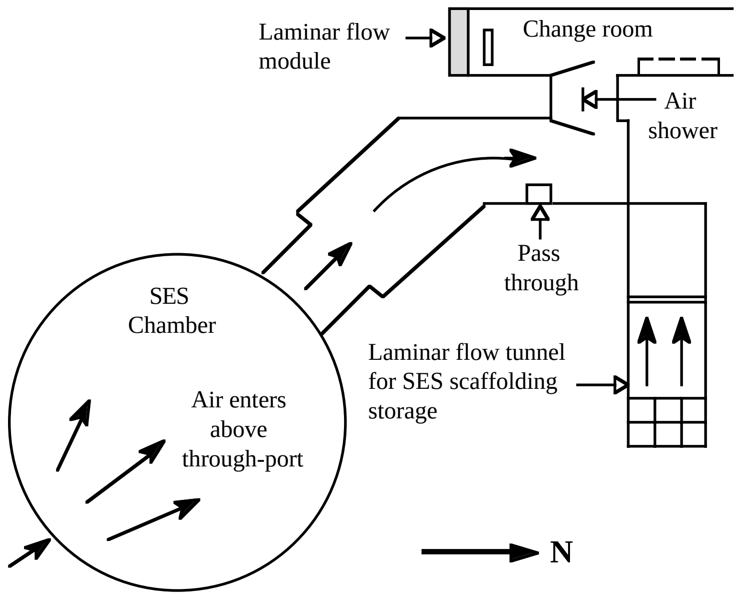
SIZE	18m L x 11m W x 6m H (59' x 36' x 19.7')
WEST WALL FILTER BANK	1,982 m^3/min (70,000 ft^3/min) - horizontal flow
AIR VELOCITY	30m/min (100'/min), minimum
TEMPERATURE	21 ± 3° C (70 ± 5° F)
RELATIVE HUMIDITY	48 ± 4%
RF WAVEGUIDES	At entrance and exit
ENTRANCE (HARDWARE)	Double door: 5.6m W x 5.4m H (20.0' x 19.0')
CLEANLINESS	Class 10,000 (M5.5)
OTHER PARAMETERS	The walls and exposed steel are painted with an epoxy paint to keep particle generation to a minimum. The concrete floor has a polyurethane coating.

2.4.3 MB C220 VIBRATION TEST CELL

SIZE	8.8m L x 8.2m W x 15.5m H (29' x 27' x 51')
CEILING FILTER BANK	1,416 m^3/min (50,000 ft^3/min) - vertical flow
AIR VELOCITY	19.8m/min (65'/min), minimum
TEMPERATURE (NOMINAL)	21° C (70° F)
RELATIVE HUMIDITY	48 ± 4%
PASS THROUGH WINDOW/DOOR	Basement level/Bldg. 10, first floor
PERSONNEL ENTRY	Basement level through NE corner
CLEANLINESS	Class 10,000 (M5.5)
OTHER SERVICES	electrical, telephone and intercom, compressed dry nitrogen, outlets for central vacuum
OTHER PARAMETERS	The walls and exposed steel are painted with an epoxy paint to keep particle generation to a minimum. The floor has a torginol seamless quartz coating.

2.4.4 SPACE ENVIRONMENT SIMULATOR (SES)

VACUUM CHAMBER SIZE	8.2m (27') diameter x 12.2m H (40')
AIR FLOW	283m^3/min (10,000ft^3/min)
TEMPERATURE (NOMINAL)	21° C (70° F)
RELATIVE HUMIDITY	below 60%
ANTEROOM	7.6m L x 3.1m W (25' x 10')
AIR FLOW	28.3m^3/min (1,000ft^3/min)
EAST WALL	Small parts passageway
NORTHWEST CORNER	Change room and air shower, basement level
CLEANLINESS	Class 10,000 (M5.5)
OTHER SERVICES	electrical, compressed dry nitrogen, outlets for central vacuum
OTHER NOTES	When the chamber door is open and the chamber clean air supply is on, air flows out of the chamber, down the length of the anteroom, and out through a louvered duct at the north end. When chamber door is closed, a small auxiliary blower/filter unit supplies filtered air into the anteroom.



SES CHAMBER (FACILITY 290)

2.4.5 CLEANROOM TENTS

BUILDING 7 HIGH BAY (150 TENT)	
SIZE	6.1m W x 9.1m L x 4.7m H (20' x 30' x 15.4')
AIR FLOW	1,303 m^3/min (46,000 ft^3/min) - vertical flow
CLEANLINESS	Class 10,000 (M5.5)
CRANE	227 Kg (500 lb) hoist
AIR VELOCITY	30m/min (100'/min)
ENTRANCE	6.1m W x 4.7m H (20' x 15.4') roll up curtain
TENT MATERIAL	anti-static polyethylene
TEMPERATURE/HUMIDITY	Building 7 HVAC

BUILDING 10 HIGH BAY (BIG TOP TENT)	
SIZE	11.3m W x 5.5m L x 5.3m H (37' x 18' x 17.5')
AIR FLOW	1,869 m^3/min (66,000 ft^3/min) - horizontal flow
CLEANLINESS	Class 10,000 (M5.5)
AIR VELOCITY	30m/min (100'/min)
ENTRANCE	5.5m W x 5.3m H (18' x 17.5') roll up curtain
TENT MATERIAL	305 micron (12 mil) PVC
TEMPERATURE/HUMIDITY	Building 10 HVAC

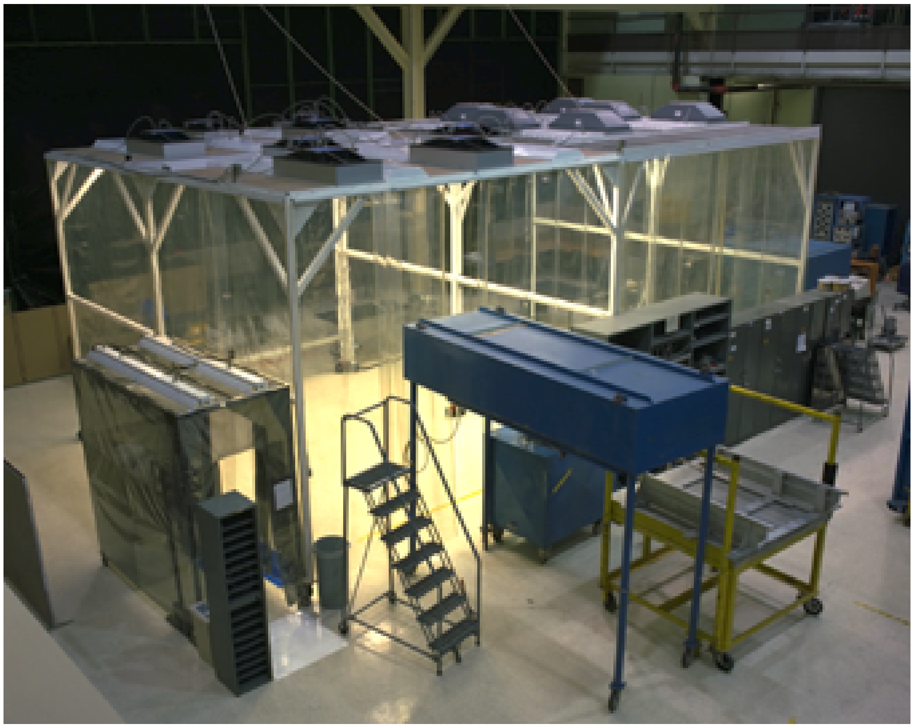
BUILDING 10 HIGH BAY CLEAN TENT

2.4.6 SPECIAL PAYLOADS OPERATIONS AND TESTING (SPOT) CLEAN TENTS

DESCRIPTION: There are four (4) movable SPOT tents that may be used separately, or together, to provide integration and test areas. The down-flow tents have wheels attached to their legs for easy positioning. Two of the four tents have crane access hatches in the ceiling for payload handling.

MODE OF OPERATION: Normally, the tents are monitored each week when in use, depending on the protocol established by the user. The tents are cleaned on an "as required" basis, and cleanroom garments are supplied as required by the cleanliness specification and project activity level.

SPOT CLEAN TENTS	
SIZE	6.1m L x 4.9m W x 4.9m H (20' x 16' x 16')
AIR VELOCITY	27m/min (90'/min)
CLEANLINESS	Class 100,000 (M6.5)
TEMPERATURE/HUMIDITY	Not controlled (subject to building's ambient conditions)
OTHER PARAMETERS	Wheels on all four legs, crane access hatch in ceiling on certain tents, static dissipative tent material



SPOT CLEAN TENT

2.4.7 PORTABLE DOWN FLOW TENTS

PORTABLE DOWN FLOW TENTS	
SIZE	1.22m W x 2.44m L x 3.66m H (4' x 8' x 12')
CLEANLINESS	Class 10,000 (M5.5)
TEMPERATURE/HUMIDITY	Not controlled (subject to building's ambient conditions)
SUPPORT	Free standing (usually have wheels on all four legs)
OTHER NOTES	Tents can be interlocked to form a 2.44m W x 2.44m L (8' x 8') module. They have side curtains of anti-static nylon, and ceiling-installed fluorescent lights. Blower units are either integral in the ceiling or stand-alone units on the floor.

2.4.8 UNIDIRECTIONAL FLOW CLEAN BENCH

Several unidirectional flow clean benches are available. The working areas range from 1.22m (4') wide, 0.61m (2') deep, and 0.61m (2') high, to 1.52m (5') wide, 0.91m (3') deep, and 0.91m (3') high. The entire back wall of the clean bench is a high efficiency filter through which air passes at 30m/min (100'/min). The unit has no air conditioning, but may containing lighting. These benches can be maintained at an air cleanliness classification of class 100 (M3.5).

UNDIRECTIONAL FLOW CLEAN BENCH

2.4.9 PORTABLE PARTICLE COUNTERS

There are four 0.028m^3/min (1.0 ft^3/min) and two 0.0028m^3/min (0.1 ft^3/min) portable automatic particle counters. The particle counters can be used for certifying cleanrooms and other cleanroom devices.

2.4.10 PRESSURE, TEMPERATURE AND HUMIDITY MONITORING

Provisions have been made to monitor room air pressure, temperature, and humidity in the CIA, SCA, RFI, and MB C220 vibration test cell. Each area is equipped with temperature and humidity chart recorders and a Magnehelic differential pressure gauge. These are direct reading instruments whose displays are monitored by viewing them near the front windows of the cleanrooms.

2.4.11 CONTAMINATION MONITORING AND ANALYSIS LAB

The Contamination Monitoring and Analysis Laboratory is located in the SSDIF Precision Cleaning Room. The lab is equipped with microscopes and an image analysis system for qualitative and quantitative analyses. A typical sample is taken to the lab in a clean container, the container is opened in the cleanroom, and the sample is placed under a microscope for a particulate count. When identification of the particles is required, the sample is studied using the image analysis system or the polarizing light microscope. Photographs may be taken and saved. After the contaminant has been identified, it can be traced to its origin, and steps can be taken to eliminate the source.

2.4.12 SPACECRAFT SYSTEMS DEVELOPMENT AND INTEGRATION FACILITY (SSDIF), BUILDING 29

DESCRIPTION: The SSDIF is a 7,989 m^2 (86,000 ft^2) facility designed to provide support for the integration and testing of spacecraft hardware. It is unique in the fact that it contains a 36,816m^3 (1.3 million ft^3) horizontal, unidirectional flow cleanroom. Additional features include: Automated Data Processing Area, Shipping/Receiving Area, Flight Hardware Storage Area, and Precision Cleaning facilities.

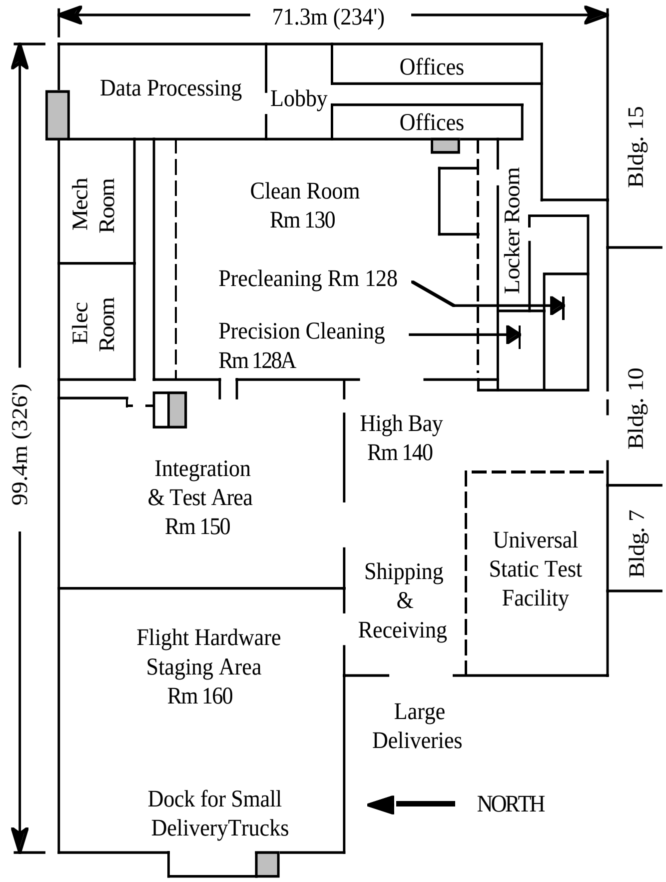
BUILDING 29 SSDIF OUTSIDE VIEW

SSDIF HIGH BAY CLEANROOM

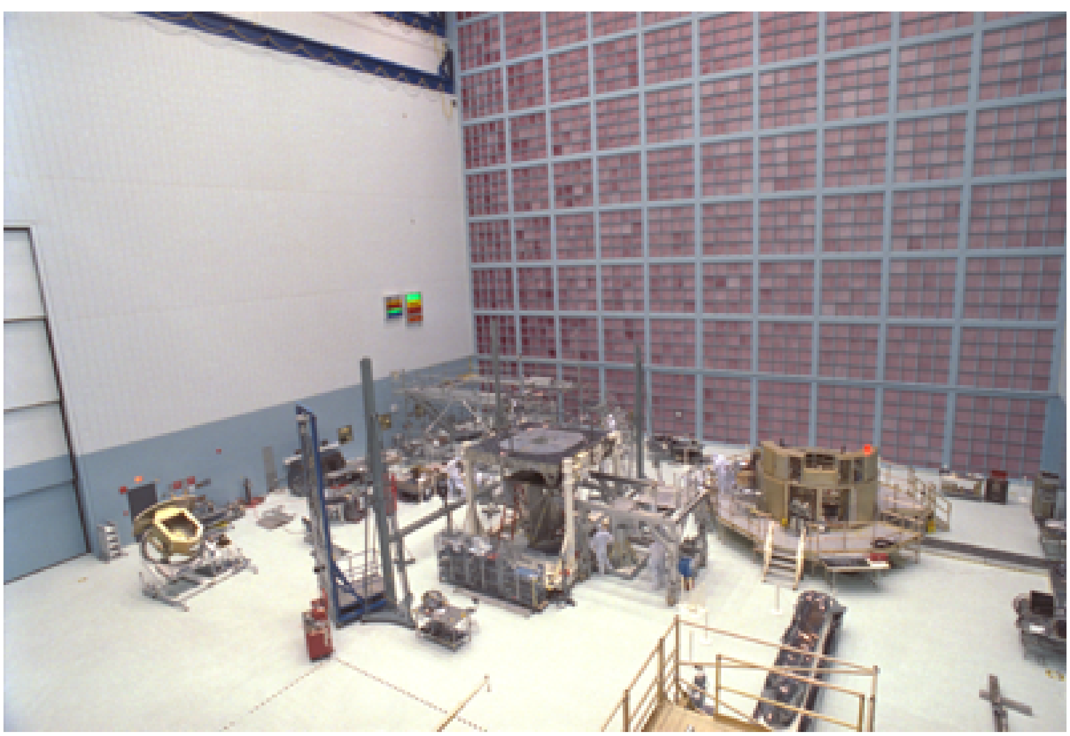
DESCRIPTION: The High Bay Cleanroom is a 1,161m^2 (12,500 ft^2), class 1,000 (M4.5), horizontal unidirectional flow cleanroom. It has been designed to support the integration and testing of flight hardware and has the capacity to accommodate two full-sized shuttle payloads simultaneously. A cable tray provides data cable access to the Automated Data Processing Room. Access to the cleanroom is via a 7.6m x 12.2m (25' x 40') overhead roll up door. Two 31,752Kg (35 ton) cranes, with hook heights of 21.0m (69') and 24.4m (80'), provide lift and transport capabilities. Materials of construction have been selected, and procedures designed, to minimize molecular and particulate contamination levels within this facility.

MODE OF OPERATION: A computer-based automatic control system monitors and controls environmental parameters on a 24-hour basis. Only approved personnel and materials are allowed to enter the cleanroom, and procedures are strictly enforced to maintain cleanliness of the facility. On-site contamination control personnel provide cleanroom support services such as: certification, monitoring, facility cleaning, maintenance of the change room, and precision cleaning.

SIZE	38m L x 30m W x 27m H (125' x 100' x 89')
CLEANLINESS	Class 1,000 (M4.5) Automatic real time monitoring
AIR VELOCITY	30m/min (100'/min), minimum
TEMPERATURE	18.3 to 23.9° C (65 to 75° F)
RELATIVE HUMIDITY	48 ± 4%
ENTRANCE (HARDWARE)	Roll up door: 7.6m W x 12.2m H (25' x 40')
NORTH WALL HEPA FILTER BANK	836m^2 (9,000 ft^2) @ 25,488 m^3/min (900,000 ft^3/min) - horizontal flow
BONDED STORAGE	Two identical areas, one atop the other
CRANES: 2 ea of 31,752 Kg (35 ton)	Hook heights of 21.0m (69') and 24.4m (80')
OTHER SERVICES: central vacuum cleaning system, compressed air and nitrogen, intercoms, telephones, video monitoring	Vacuum outlets near columns C-2, C-8, D7-8, E-2, F-4, F-6 (Other services located as required)



BUILDING 29 FIRST FLOOR PLAN



SSDIF HIGH BAY CLEANROOM

SSDIF PRECISION CLEANING ROOM

DESCRIPTION: The Precision Cleaning Room is a 55m^2 (592 ft^2), Class 1,000 (M4.5), horizontal, unidirectional flow cleanroom. It was designed to supply precision cleaning services for spacecraft hardware and ground support equipment. This area contains the necessary services, equipment, and supplies, including a Quadrex Shear Stress Precision Cleaning System.

MODE OF OPERATION: The facility is staffed with trained precision cleaning personnel providing a variety of cleaning services. Complete, detailed procedures govern all applications, and QA personnel provide inspection capability for all cleaned parts. Access to the facility is restricted, and operations are supported by a 46m^2 (500 ft^2) Pre-Cleaning Room.

SIZE	8.5m L x 6.4m W x 3.0m H (28' x 21' x 10')
CLEANLINESS	Class 1,000 (M4.5) Periodic monitoring
AIR VELOCITY	30m/min (100'/min), minimum
TEMPERATURE	18.3 to 23.9° C (65 to 75° F)
RELATIVE HUMIDITY	40 to 50%
ENTRANCE (HARDWARE)	Two 1.83m (6') double doors, one with airlock; also a pass-through
HEPA FILTER BANK	26m^2 (280 ft^2) @ 793 m^3/min (28,000 ft^3/min) - horizontal flow
OTHER SERVICES: central vacuum cleaning system, shear stress precision cleaning system, compressed nitrogen, video monitoring, communication system	Services are located as required - See facility layout drawings for details.

3.0 FACILITY SUPPORT SERVICES
3.1 ELECTRICAL POWER
3.1.1 NORMAL HOUSE POWER

Normal house power in the Bldgs. 7, 10, 15, 29 complex consists of the following circuits:

Voltage (AC)	Hz	Phase	Current (Amp)
120/208	60	1	up to 30 per outlet
277/480	60	3	up to 100 per outlet

Designated circuits in Bldgs. 7 and 10 can be backed up by an emergency power source. It should be noted that all transformers are Y connected with the center tap grounded. Instrument grounding plates are available throughout the complex.

3.1.2 EMERGENCY POWER SYSTEMS

DESCRIPTION: The emergency power systems for the test facilities in Buildings 7 and 10 consist of a 250-KVA diesel generator and a 500-KVA diesel generator, respectively. The generators and their associated switchgear cabinets are permanently installed at each location.

MODE OF OPERATION: Each generator will start and transfer automatically to the building supply when commercial power has been lost longer than 15 seconds. Due to the limited capacity of these units, normal procedure after a power failure is to initiate an orderly restart of selected facilities up to the capacity of the emergency system. For a power outage, test conditions are maintained for at least one hour by the emergency generator, or until commercial power has been restored satisfactorily.

BLDG. 10 EMERGENCY GEN.

3.2 HIGH PRESSURE GN_2 GENERATING AND STORAGE SYSTEMS (FACILITIES 258 AND 263)

DESCRIPTION: There are separate high pressure GN_2 generating and storage systems for Buildings 7 and 10. The Building 7 system is comprised of a liquid pressurization pump, an ambient air heat exchanger, and a manifolded rack of forged steel gas storage bottles. The Building 10 system has a dual pump arrangement with a single ambient air heat exchanger. The Buildings 7 and 10 GN_2 storage systems are connected, and both are filled by the Building 10 GN_2 system, with the Building 7 GN_2 system serving as a hot backup.

MODE OF OPERATION: The high pressure pump increases the liquid pressure to 13.8Mpa (2,000 psig). The liquid is evaporated in the heat exchanger and transferred to the storage bottles which are maintained at 14.1Mpa (2,045 psig) maximum. The gas is withdrawn for use in each building after a two-stage pressure reduction to 2.4Mpa (350 psig) and 0.69Mpa (100 psig), respectively.

PARAMETERS

GN_2 generation:	227 standard m^3/hr (8,000 ft^3/hr) each pump
Storage capacities:	Bldg. 7 - 719 standard m^3 (25,400 ft^3) Bldg. 10 - 2,322 standard m^3 (82,000 ft^3)

PHYSICAL CHARACTERISTICS

	Building 7	Building 10
Pressurizing engine pump:	1	2
LN_2 storage dewar - 1,893 lit (500 gal):	1	1
Vaporizing heat exchanger:	1	1
Storage bottles:	3	25

BLDG 10 VAPORIZER

BLDG 10 GN_2 STORAGE BOTTLES

3.3 CRANE CAPACITIES

It is recommended that crane users conduct a site inspection to verify limit switch repeatability if their job requires hook heights within a few inches of the limits shown below. For example, gear-type limit switches may repeat within only a couple of inches on some cranes.

*TYPE (Except as otherwise noted, the cranes are bridge cranes.)
a - Variable hoist control; b - Trolley crane (no bridge); c - Hoist only (no trolley or bridge); d- Dual trolley; e - Wooden traversing

Bldg/Crane No.	Location	*Type	Capacity Kg/(Ton)	Hook Height m/(ft & in)
7-4	Rm 040, Vib Lab		6,804/(7.5)	13.5/(44'3") To Basement 7.4/(24'3") To B10 Floor
7-6	Rm 036, Vib Lab		6,804/(7.5)	13.2/(43'4") To Basement 7.1/(23'4") To B10 Floor
7-7	Rm 034, Vib Machine Shop	b	227/(0.25)	4.6/(14'11")
7-8	Rm 032, Hydraulic Shaker	b	1,814/(2)	4.5/(14'9")
7-9	Rm 026, Vib Lab	b	1,814/(2)	4.4(14'6")
7-10	Rm 026, Vib Lab	b	1,814/(2)	4.7/(15'5")
7-13	Truck Lock		9,072/(10)	10.6/(34'8")
7-14	Rm 190A, Integration	b	1,814/(2)	4.3/(14'1")
7-15	Rm 190A, Integration	b	1,814/(2)	4.2/(13'11")
7-16	High Bay Lab		4,536/(5)	8.5(28')
7-17	High Bay Lab		4,536/(5)	8.5/(28')
7-18	SCA Clean Room	a	4,536/(5)	8.3/(27'3")
7-19	CIA Clean Room	a	6,804/(7.5)	13.1/(43'1") To Basement 8.6/(28'4") To 1st Floor
7-30	Acoustic Chamber		6,804/(7.5)	8.7/(28'7")
10-1	High Bay Lab	a	13,608/(15)	20.1/(66')
15-2	High Bay Lab	a	6,804/(7.5)	11.9/(39'1")
15-3	HCC Rotunda (east)	b	2,722/(3)	7.7/(25'3")
15-4	HCC Rotunda (west)	b	6,804/(7.5)	7.9/(26')
15-5	Modal Test Facility	a	907/(1)	6.7/(22')
15-6	Modal Test Facility	a	454/(0.5)	5.8/(19')
15-7	Modal Test Facility	d	454/(0.5)	4.9/(16')

Bldg/Crane No.	Location	*Type	Capacity Kg/(Ton)	Hook Height m/(ft & in)
29-1	High Bay Clean Room	a	31,752/(35)	21/(69')
29-2	High Bay Clean Room	a	31,752/(35)	24.4/(80')
29-3	Rm 135, Ship/Receive	a	31,752/(35)	20.3/(66'9")
29-4	Rm 136, Flt Hdwe Staging	a	31,752/(35)	20.2/(66'4")
29-5	Rm 150	a	4,536/(5)	7.6/(25')
303 30-8, Sml Coil	Central Coil Building	e	1,089/(1.2)	7.6/(25')
305 30-1, Lge Coil	Inner Truck Lock	b	2,722/(3)	4.2/(13'10")
305 30-2, Lge Coil	South Side of Bldg	c	2,268/(2.5)	6.7/(22')
305 30-3, Lge Coil	Coil Centerline	c	2,268/(2.5)	5.8/(19')
305 30-4, Lge Coil	Outer Truck Lock	b	2,268/(2.5)	5.8/(19')

MANUAL-TYPE HYDRASET ON CRANE

3.4 HYDRASETS

Hydrasets are hydraulic, remotely-controlled lifting devices which are placed between the crane hook and the load. They can position a load vertically in increments of 0.025mm (0.001"). Each is proof-tested at 200% of the rated load, and tested at 125% of payload, before lifting flight hardware. All are exercised monthly; this is in addition to other routine testing and maintenance.

POSITIVE FLUID RETENTION SYSTEM, CONSOLE-OPERATED HYDRASETS					
				Rigging Length Eye-to-Eye	
Qty.	Capacity Kg/(Ton)	Usable Range Kg/(Lb)	Stroke cm/(inch)	Min cm/(inch)	Max cm/(inch)
1	454/(0.5)	91-363/(200-800)	30.5/(12.00)	59.1/(23.25)	89.5/(35.25)
1	907/(1.0)	181-726/(400-1,600)	15.2/(6.00)	65.4/(25.75)	80.0/(31.50)
3	907/(1.0)	181-726/(400-1,600)	31.3/(12.32)	80.8/(31.81)	112.1/(44.13)
1	2,268/(2.5)	454-1,814/(1,000-4,000)	14.6/(5.75)	65.4/(25.75)	80.0/(31.50)
3	2,268/(2.5)	454-1,814/(1,000-4,000)	30.5/(12.00)	82.9/(32.63)	113.4/(44.63)
4	4,536/(5)	907-3,629/(2,000-8,000)	30.5/(12.00)	83.2/(32.75)	113.7/(44.75)
2	9,072/(10)	1,814-7,258/(4,000-16,000)	15.2/(6.00)	79.7/(31.38)	94.9/(37.38)
4	9,072/(10)	1,814-7,258/(4,000-16,000)	30.5/(12.00)	95.6/(37.63)	126.1/(49.63)
1	18,144/(20)	3,629-14,515/(8,000-32,000)	30.5/(12.00)	109.2/(43.00)	139.7/(55.00)
MANUAL-TYPE HYDRASETS					
2	454/(0.5)	91-363/(200-800)	30.5/(12.00)	56.5/(22.25)	87.0/(34.25)
2	907/(1.0)	181-726/(400-1,600)	30.5/(12.00)	65.4/(25.75)	95.9/(37.75)
1	2,268/(2.5)	454-1,814/(1,000-4,000)	30.5/(12.00)	65.4/(25.75)	95.9/(37.75)
1	4,536/(5)	907-3,629/(2,000-8,000)	15.2/(6.00)	65.4/(25.75)	80.6/(31.75)
1	4,536/(5)	907-3,629/(2,000-8,000)	30.5/(12.00)	65.4/(25.75)	95.9/(37.75)
1	9,072/(10)	1,814-7,258/(4,000-16,000)	30.5/(12.00)	83.2/(32.75)	113.7/(44.75)

3.5 LIFTING AND HANDLING DEVICES

The following hardware handling and personnel lifting devices are available:

Type	Capacity Kg (lb)	Platform Size m/(ft)	Lift Height m/(ft)
Fork Lifts			
Clark	7,031/(15,500)	1.22 x 1.83/(4 x 6)	3.05/(10)
Yale	4,536/(10,000)	1.22 x 1.22/(4 x 4)	3.05/(10)
Clark	4,309/(9,500) @<152" H 3,402/(7,500) @>152" H	1.22 x 1.22/(4 x 4)	7.62/(25)
Schreck	1,814/(4,000)	0.91 x 0.79/(3 x 2.6)	4.72/(15.5)
Moto-Truc	1,361/(3,000)	0.91 x 0.79/(3 x 2.6)	3.35/(11)
EZ Lift (3 each)	680/(1,500)	0.69 x 0.63/(2.3 x 2.1)	1.65/(5.4)
Flat Bed Electric Truck	1,814/(4,000)	2.44 x 0.91/(8 x 3)	0.10/(0.33)
Tow Tractors			
Clark	2,268/(5,000)	N/A	N/A
PettiBone	1,361/(3,000)	N/A	N/A
Raymond (2 each)	91/(200)	N/A	N/A
Lift Tables			
Rol-Lift Pallet Jack (2 each)	2,495/(5,500)	1.22 x 0.69/(4 x 2.3)	0.15/(0.5)
Economy Lift Table (2 each)	454/(1,000)	0.91 x 0.61/(3 x 2)	0.31/(1)
Raymond Pallet Jack	454/(1,000)	1.22 x 0.69/(4 x 2.3)	0.15/(0.5)
Personnel Lifts			
Upright	907/(2,000)	3.66 x 2.13/(12 x 7)	10.97/(36)
Mark 26	454/(1,000)	1.17 x 2.49/(3.8 x 8.2)	7.92/(26)
Mark 20 (2 each)	363/(800)	0.76 x 2.49/(2.5 x 8.2)	6.10/(20)
Upright	340/(750)	1.68 x 0.91/(5.5 x 3)	5.49/(18)
Upright Air-Deck	227/(500)	2.44 x 0.91/(8 x 3)	7.52/(24.7)
JLG	227/(500)	0.91 x 0.61/(3 x 2)	13.7/(45)
Upright TL49	215/(475)	0.68 x 1.30/(2.25 x 4.25)	15.1/(49.5)
Balleymore	159/(350)	0.66 x 0.66/(2.2 x 2.2)	11.0/(36)
Upright	136/(300)	0.61 x 0.61/(2 x 2)	5.79/(19)

3.6 DOORWAY AND OTHER CLEARANCES FOR BUILDINGS 7, 10, 15, AND 29

These dimensions are presented to assist the test program coordinator in pretest planning efforts. Note that building modifications and the addition of new building appurtenances may cause these dimensions to change, or to obstruct the free movement of test items. For items which approach clearance sizes, or for bulky, shuttle-size experiments, payload handling procedures should be prepared based on a site visit.

Description	Location	Dimensions meter/(ft & in)
Roll Up Door	B7 SCA - North	5.94 W x 5.97 H (19'6" x 19'7")
Roll Up Door	B7 SCA - South	5.94 W x 5.97 H (19'6" x 19'7")
Roll Up Door	B7 to B10	5.84 W x 5.87 H (19'2" x 19'3")
Roll Up Door	B10 to B15	5.94 W x 6.07 H (19'6" x 19'11")
Roll Up Door	B15 to Outside	7.29 W x 6.27 H (23'11" x 20'7")
Roll Up Door	B7 Truck Lock to Outside	4.62 W x 4.50 H (15'2" x 14'9")
Roll Up Door	B7 Truck Lock to B10	4.88 W x 3.94 H (16' x 12'11")
Roll Up Door	B7 Truck Lock to Rm 190 (Integration Area)	3.63 W x 4.19 H (11'11" x 13'9")
Roll Up Door	B7 Corridor to Rm 190 (Integration Area)	3.38 W x 4.19 H (11'1" x 13'9")
Roll Up Door	SCA to CIA	3.67 W x 3.35 H (12'1/2" x 11')
Roll Up Door	B29 Rm 130 Clean Rm to Rm 140 Ship/Receive	7.62 W x 12.19 H (25' x 40')
Roll Up Door	B29 Rm 140 Flt Hdwe Staging Area to B10	7.62 W x 12.19 H (25' x 40')
Roll Up Door	B29 Rm 160 Flt Hdwe Staging to Outside	5.03 W x 5.49 H (16'6" x 18')
Roll Up Door	B29 Rm 160 Flt Hdwe Staging to Rm 140 Ship/Receive	6.10 W x 5.94 H (20' x 19'6")
Roll Up Door	B29 Rm 150 High Bay to Rm 140 Ship/Receive	7.62 W x 7.62 H (25' x 25')

Description	Location	Dimensions meter/(ft & in)
Roll Up Door	B29 Rm 140 Ship/Receive to Outside	7.62 W x 7.62 H (25' x 25')
Walkway	Bridge over B7 - B10 Corridor	5.49 W x 5.44 H (18' x 17'10")
Air Conditioning Duct	Duct over B7 - B10 Corridor	5.49 W x 5.84 H (18' x 19'2")
Hinged Doors (2 each)	Large RFI to SCA	5.64 W x 5.46 H (18'6" x 17'11")
Hinged Doors (2 each)	B7 Rm 036 & B7 Rm 040 (C220 Vib Cells) to B10	4.93 W x 8.97 H (16'2" x 29'5")
Hinged Doors (2 each)	B7 Basement to B335 Vib Cell	2.44 W x 5.08 H (8' x 16'8")
Hinged Doors (2 each)	Acoustic Chamber to B10	4.55 W x 10.31 H (14'11" x 33'10")
Hinged Doors (2 each)	HCC Rotunda to B15	7.31 W x 7.16 H (24' x 23'6")
Hinged Doors (2 each)	Small RFI	2.13 W x 2.21 H (7' x 7'3")
Elevator	B7 Freight Elevator	3.05 W x 2.92 L x 2.29 H (10' x 9'7" x 7'6")
Elevator	B7 Basement Floor to B7 Freight Elevator Floor Level	1.78 W x 2.57 L x 2.64 H (5'10" x 8'5" x 8'8")
Elevator	B7 Personnel Elevator	1.17 W x 1.93 L x 2.13 H (3'10" x 6'4" x 7')
Floor Opening	B10 near B7 Truck Lock	2.74 W x 3.05 L (9' x 10')
Floor Opening	B10 near SES Chamber	3.05 W x 6.10 L (10' x 20')
Floor Opening	B7 near Freight Elevator	3.91 W x 5.13 L (12'10" x 16'10")

3.7 AIR BEARING SUPPLY STATIONS

The house air system delivers compressed air at 621Kpa (90psig) pressure with a maximum volume of $2.83m^3$($100ft^3$)/min. Connections are via a Hansen 2.54cm (1") quick disconnect and are available at the following locations:

Building 7 1st Floor Locations	Building 10 1st Floor Locations	Building 29 1st Floor Locations
• SCA cleanroom, north wall • 0.9m (3') east of column D7 RB • Column D10 RB • Column D13	• Column 16 EX • 4.6m (15') west of column 23 EX • Column 16 J	• Cleanroom near column F-6 • High bay near column J-9 • High bay near Column D6-10

3.8 AIR BEARINGS

DESCRIPTION: Air bearings and matching jacks provide both mobility and vertical height adjustment of the load. By bolting the air bearings to an object and applying air pressure, the object rides on a cushion of air and is easily moved and maneuvered. The jacks, which are attached to the air bearings, are needed to raise the load off the floor before air pressure is applied.

Quantity	Size	Capacity
4	41cm (16") diameter	907 Kg (2,000 lb)
4	56cm (22") diameter	1,814 Kg (4,000 lb)
4	71cm (28") diameter	2,722 Kg (6,000 lb)
4	86cm (34") diameter	4,536 Kg (10,000 lb)
4	30cm L x 30cm W (12" x 12")	907 Kg (2,000 lb)
4	69cm L x 69cm W (27" x 27")	5,443 Kg (12,000 lb)

AIR BEARING

3.9 GN_2 PURGE OUTLETS

DESCRIPTION: Gaseous nitrogen is available for purge at various locations in the cleanrooms. A GN_2 supply can be installed for special applications at any location in the Building 7/10/15/29 complex when defined by the experimenter in advance.

Location	Supply Line	Maximum Delivery Pressure	Connection
SCA Cleanroom (4 locations)	0.95cm (3/8") nominal	621Kpa (90psig)	0.64cm (1/4") Swagelok fitting
CIA Cleanroom (2 locations)	0.95cm (3/8") nominal	621Kpa (90psig)	0.64cm (1/4") Swagelok fitting
SSDIF Cleanroom (6 locations)	1.3cm (1/2") nominal	621Kpa (90psig)	0.64cm (1/4") Swagelok fitting
SES Chamber (3 locations)	1.3cm (1/2") nominal	621Kpa (90psig)	0.64cm (1/4") Swagelok fitting
Acoustic Chamber (1 location, column 16K)	0.95cm (3/8") nominal	621Kpa (90psig)	0.64cm (1/4") Swagelok fitting
Vibration Cell, Rm 36 (1 location)	0.95cm (3/8") nominal	621Kpa (90psig)	0.64cm (1/4") Swagelok fitting
Vibration Cell, Rm 40 (1 location)	0.95cm (3/8") nominal	621Kpa (90psig)	0.64cm (1/4") Swagelok fitting
Thermal Vacuum Chambers, Bldg. 7 (At each facility)	Varies	621Kpa (90psig)	Varies (All can be adapted to 1/4" Swagelok fitting)

3.10 LN_2 FILL STATIONS

DESCRIPTION: LN_2 stations for dewar filling are provided in the locations shown:

Location	Supply Line	Maximum Delivery Pressure	Connection
Bldg. 7 Basement, near column G-6	1.3cm (1/2") nominal	172Kpa (25psig)	1.3cm (1/2") American National fitting
West wall - Facility 255 LN_2 storage shed	1.3cm (1/2") nominal	172Kpa (25psig)	1.3cm (1/2") American National fitting

3.11 LN_2 STORAGE VESSELS

Large quantities of liquid nitrogen are maintained to provide cryogenic cooling of cryopumps, cold fingers, diffusion pump cold traps and shrouds of the thermal vacuum chambers in Buildings 7 and 10, and as a supply for the high pressure gas generators. Also, small portable vessels can be filled at the Building 7 facility.

3.11.1 BUILDING 7, 106K LITER (28K GAL) DEWAR (FACILITY 255)

DESCRIPTION: This double-walled, vacuum-jacketed storage vessel is comprised of two concentric, horizontal cylinders. The outer shell, made of carbon steel, is 18.3m (60') long by 3.7m (12') in diameter. The inner tank, fabricated from stainless steel, has a capacity of 106K liters (28,000 gallons) of LN_2 with a 5,299 liter (1,400 gallon) ullage volume. An ambient temperature vaporization coil maintains a tank pressure of 172Kpa (25psig). Valves are provided to control the filling and withdrawal of the cryogenic fluid.

MODE OF OPERATION: Insulated plumbing conducts the cryogenic fluid to a distribution manifold in Building 7, where it is transferred as required to each chamber and withdrawal station through insulated or vacuum-jacketed lines.

3.11.2 BUILDING 10, 242K LITER (64K GAL) DEWAR (FACILITY 257)

DESCRIPTION: This double-walled, vacuum-jacketed LN_2 dewar is comprised of two concentric spheres supported by tubular columns. The 7.9m (26') diameter inner vessel is constructed of welded aluminum plates and the 8.5m (28') diameter outer casing is constructed of welded steel plate. The inner tank has a capacity of 242K liters (64,000 gallons) with a 22.7K liter (6,000 gallon) ullage volume. An ambient temperature vaporization coil provides a tank pressure of 172Kpa (25psig). Valves are provided to control the supply and withdrawal of LN_2.

MODE OF OPERATION: Insulated plumbing conducts the cryogenic fluid to a distribution panel in the basement of Building 10, where it is directed as required to the cryopumps, the thermal system, and the shroud LN_2 recirculating system.

APPENDIX - A

MECHANICAL SYSTEMS CENTER

ENVIRONMENTAL TEST AND INTEGRATION

USER’S GUIDE

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MSC ENVIRONMENTAL TEST AND INTEGRATION USER'S GUIDE

1.0 Introduction

This User's Guide provides an introduction to the utilization of the Goddard Space Flight Center (GSFC) Mechanical System Center (MSC) Environmental Test and Integration Facilities. Included is a brief description of the organization along with the point of contact for those wishing to have integration and testing work performed. Following this description is an overview of the facilities and capabilities. Also included is a list of documents required to obtain integration and testing services as well as special considerations and suggestions in order to make things easier for users and ensure the best service possible.

2.0 Organizational Responsibilities

The MSC, Code 540, is responsible for management of the GSFC environmental test and integration facilities located in Buildings 7, 10, 15, 29, and at the Magnetic Test Facility. Test engineering and the operation and maintenance of the facilities within the MSC is the responsibility of the Environmental Test Engineering & Integration Branch, Code 549. Supporting Code 549 in the administration of the testing workload, identifying the funding and personnel resource requirements, and developing the environmental test verification plans is the Environmental Project Engineering Section, Code 549.1.

2.1 Organizational Contacts

In order to assist in the planning for, and expediting of, the item to be tested through the facility complex, Figure 1 identifies the principal contacts. The first point of contact should be the Environmental Project Engineering Section. An Environmental Project Engineer is assigned for each project to provide assistance in coordinating and expediting work through the facilities. Other facility contacts will provide assistance in determining specific engineering and facility resources required to accomplish the test program. The assigned Environmental Project Engineer is the point of contact in scheduling tests and ensuring that test requirements are achieved.

2.2 Environmental Project Engineering

The Environmental Project Engineering (EPE) Section provides mid-level and senior-level engineers who develop an environmental verification plan to ensure that your test item has been tested to the GSFC specification tailored to your flight project. EPE managers are involved throughout the project life, and develop the verification plan, generate cost estimates and work directives, and assist in coordinating the test facility scheduling. EPE managers support in-house and out-of-house GSFC projects by serving on Source Evaluation Boards/Tech Panels, developing/

Figure 1. Code 549 Contacts For Environmental Test and Integration

Environmental Test Engineering & Integration Branch (Code 549)

Environmental Project Engineering
Section Head (Code 549.1)
Bldg. 7-Rm. 157
(301) 286-0409

Structural/Dynamic Testing
Section Head (Code 549.2)
Bldg. 7-Rm. 165
(301) 286-6480

Electromagnetic Testing
Section Head (Code 549.3)
Bldg. 7-Rm. 155
(301) 286-6201

Space Simulation Testing
Section Head (Code 549.4)
Bldg. 7-Rm. 163
(301) 286-6058

reviewing statements of work for request for proposals (RFP), and reviewing test plans and procedures. Initial contacts for both GSFC supported programs and reimbursable projects (work from other centers, DOD, etc.) should be established with this Section.

2.3 Environmental Test Engineering And Integration Branch

The Environmental Test Engineering & Integration Branch is responsible for providing the test personnel and facilities to accomplish the test program. The test facilities include thermal vacuum chambers, vibration shakers, static and dynamic loading facilities, and electromagnetic interference generators. The Branch is assisted by a support contractor who operates and maintains the facilities. The Branch also generates the detailed manpower estimates to perform the required test, and assesses the availability of the facilities. Any requirements for new or modified facilities or expanded test capabilities should be addressed through this office. While undergoing the various tests in thermal vacuum, vibro-acoustics or EMC, a test engineer for each area is assigned to assist in test set up, instrumentation, and data analysis. The test engineer interacts with the project early in the design and fabrication phase to assist with test issues. A project provided test plan is required well in advance of any scheduled tests so that special requirements may be met and a test procedure can be prepared by the Branch.

3.0 Facilities Overview

The Environmental Test Engineering & Integration Branch maintains a full spectrum of facilities needed for complete spacecraft and instrument mechanical integration and environmental testing. When coupled with project and Code 549 expertise, the facilities provide the outstanding, comprehensive capabilities required to execute a complete spacecraft integration and test (I&T) program. All facilities except the Magnetic Test Facility are contained within the same building complex (Buildings 7, 10, 15, and 29). The Magnetic Test Facility is located off the main campus to provide magnetic isolation and control. In summary, facilities are provided for thermal vacuum, thermal balance, thermal vacuum bakeout, electromagnetic interference, magnetic, static load, vibration, centrifuge, separation, shock, modal and deployment testing, and for mass properties measurements, data analysis, and data collection. Other facilities important to the I&T process contained within the complex are clean rooms, clean benches, cleaning facilities, optical alignment and measurements, and spin balancing, along with areas for cable fabrication and thermal blanket fabrication.

4.0 Engineering And Support Capabilities

4.1 Environmental Project And Test Engineering

The knowledge, skills, and experience of the personnel working in the organization provide the essential technical link allowing the facilities to be used to conduct tests. Branch engineers are assigned to work with specific projects early in the planning phase; and continuously through the project execution cycle to facilitate advanced preparation and design of the test series. Verification engineering support is provided as requested to develop a project specific Environmental Verification Plan. Project engineers are encouraged to use this expertise early in project planning phases to best use test engineering contributions. Also, the personnel are capable of providing design consultation to project engineers in specific disciplines related to the major areas of environmental testing: thermal/vacuum, structural, and electromagnetic.

4.2 Procedure Writing

Prior to any test being executed by Code 549, a test procedure must be written. The procedure takes information made available in the test plan (written by the project) and adds facility procedure information. Code 549 personnel write these procedures using the test plan and direct interaction with the project engineers for information. Generally speaking, the nature and complexity of the procedures will vary significantly from one test to another and from one test item to another.

4.3 Off-Site I&T Support

GSFC often manages spacecraft and instrument development programs that are executed at contractor sites. During the I&T phase of these programs, it is often advantageous for program managers to draw upon experienced personnel to consult in these specialized areas. Code 549 has available both civil servants and contractor personnel who are experienced in test support planning and conducting spacecraft environmental test programs. Managers are encouraged to draw on these resources during this program phase. Support in terms of test plan and procedure review, contractor site inspection and review, test oversight, and post test data analysis is available.

4.4 Analysis

Expertise and tools are available to perform detailed design analyses to support both test design and flight hardware design. In terms of testing, many of these analyses are required for proper design of the test, and of test support systems including fixturing and custom facility modification. Experienced analysts are available to support and perform thermal, structural, electromagnetic, safety, modal, coupled loads, system’s safety, stress, finite element, and other types of analysis. Project engineers are encouraged to use this base of expertise, a base which is specifically tailored to analysis needed for test design.

4.5 Proofing

Most activity related to lifting, moving, supporting, rotating, or otherwise handling hardware, flight or otherwise, requires support hardware that has been proof tested and analyzed for strength and stability. The Environmental Test Engineering & Integration Branch maintains the capability in-house to perform all testing and analysis required to satisfy NASA and Goddard requirements for lifting and support equipment certification.

4.6 Integration

Personnel experienced in and fully capable of executing the full spectrum of work needed for spacecraft mechanical integration are available within Code 549. The difficult task of integrating separate subsystems and structures into a functioning mechanical system represents one of the most challenging tasks faced by the spacecraft I&T managers. Code 549 personnel provide the experience, tools, and facilities to properly integrate the spacecraft and ensure correct alignment and operation.

4.7 Design

The organization maintains the capability of designing all types of flight related hardware. Experienced design and analysis personnel, coupled with modern facilities, provide the ability to address a multitude of hardware design problems. These include flight hardware from small sub-elements through major subsystems; mechanical ground support equipment including handling gear, turnover dollies, etc.; and environmental test facility related hardware including facility modifications and complex fixturing. A diverse group of analysis personnel provide support to the design program to assure success and provide the documentation needed to certify flight systems.

4.8 Wire Harness Manufacturing

Flight and GSE wire harness system design, fabrication, routing, and installation capabilities are provided through the Code 549 Cable Harness Facility. Full spacecraft harness fabrication jobs have been successfully executed by Code 549’s experienced group of wiring personnel. Ground support equipment, test support, and flight cabling work can be executed by this group.

4.9 Thermal Blanket Manufacturing

Thermal blanket design, fabrication, and installation capabilities are provided through the Code 549 Thermal Blanket Facility. Experienced personnel, together with blanket fabrication facilities, provide the capability for complete spacecraft blanketing. Spacecraft thermal blanket closeout and launch site support can be provided.

5.0 Documentation Requirements

In order to insure that testing in Code 549 facilities proceeds as smoothly as possible, project technical managers or the responsible MSC test personnel must prepare certain documentation. These documents must be provided in a timely manner to ensure that required test preparations are completed prior to the test date. The approved verification plan will be used as the basis for the test program.

5.1 Test Plans

The cognizant project technical manager or component/subsystem/system lead engineer is responsible for preparing the individual test plans. Each plan is normally required 30 days before testing for components and subsystems, and as much as six months before complicated tests such as High Capacity Centrifuge loads testing or system level thermal balance/thermal vacuum testing. At a minimum, each test plan must be approved by the project manager (or representative), the test item lead engineer, the EPE, and the quality assurance representative. Each test plan will provide the information necessary to develop the facility test procedure and identify special fixturing and/or safety constraints required. A sample outline of the test plan contents is listed in Figure 2.

5.2 Test Procedures

Code 549 test personnel develop facility test procedures using project developed test plans. A unique test procedure is written for each test, even if the test is a repeat of a previously run test. The test procedure normally contains the item configuration, mounting details, instrumentation types and locations, handling/safety considerations, and data acquisition/reduction requirements. The project manager or lead engineer, EPE, Code 549 test engineer, facility engineer, and quality assurance representative (as required by project) all sign approval of the test procedure.

5.3 Work Directives

A work directive (WD) provides the authorization for the test facility support contractor to initiate work to prepare for and conduct the test. A blank WD form is included as Figure 3. The EPE assigned to the project prepares the WDs. Separate WDs are to be prepared for each test and are also to be prepared for a level of activity such as integration or clean room support. To avoid delays in performing the required tests, the initial contact for all test requests should originate with the EPE. The WD is generated from project requirements as stated in the test plan. From these requirements, the manpower and materials are estimated to complete the test. After project approval, the WD is processed and the test is initiated. The project is charged for the work performed on a monthly basis until completed. Additional work not identified in the original WD must be authorized by the EPE, and approved by the project prior to being conducted. The EPE maintains a weekly status of test charges which are available upon request.

5.4 Supporting Analyses

Lifting - All critical flight hardware test items requiring a crane for lifting must be accompanied by an approved lifting analysis. In addition, any non-flight hardware and GSE requiring a crane may need an approved lifting analysis if there is any risk to Code 549 facilities or personnel. The project is responsible for performing this analysis and the appropriate Code 549 personnel shall verify it. The analysis applicability and content is defined in the following GSFC documents: (1) Procedure for Approval of Project Related Lifting Equipment, dated November 1992; and (2) Analysis Procedure for Spreader Bar Lift Stability. These documents are available from the Code 549 Branch Office.

Figure 2. Suggested Test Plan Outline

1.0 Introduction
- 1.1 Purpose
- 1.2 Test Objectives
- 1.3 Pass/Fail Criteria
- 1.4 Test Item Description
- 1.5 Test Facility
- 1.6 Desired Test Date
- 1.7 Work Directive Number
- 1.8 Fiscal and Labor Job Order Numbers
- 1.9 Applicable Documents

2.0 Test Organization
- 2.1 Test Team

3.0 Special Precautions/Instructions
- 3.1 Safety
- 3.2 Precautions
- 3.3 Contamination
- 3.4 Emergencies

4.0 Test Requirements
- 4.1 Test Operations
- 4.2 Procedure Redlining

5.0 Data Acquisition/Reduction
- 5.1 Data Acquisition
- 5.2 Data Reduction

6.0 Support Equipment
- 6.1 Instrumentation
- 6.2 Support Equipment

7.0 Test Program
- 7.1 Test Phases/Sequence
- 7.2 Test Specification
- 7.3 Test Limits

8.0 Pre-Test Operations

9.0 Test Operations
- 9.1 Test Item
- 9.2 Test Fixturing
- 9.3 Test Setup

10.0 Post Test Operations

Figure 3. Work Directive Form (Front)

GODDARD SPACE FLIGHT CENTER
MECHANICAL SYSTEMS CENTER
CODE 549

WORK DIRECTIVE (WD)

WD NUMBER ISSUE DATE:

PROJECT FUND SOURCE MOD. NO.

FISCAL JON ESTIMATED COST LABOR JON RATE CODE APP FY

ITEM DESCRIPTION

SCH START ACT START FAC CODE SCH COMPL ACT COMPL ITEMS

EST TECH HRS SC EST ENG HRS MC TESTS RT WD REF REQUESTER FI ORG CODE

AUTHORIZED PERSON FI ORG CODE EST MATERIALS COST EST TRAVEL COST

LEVEL OF ASSEMBLY

- ☐ **1. SYSTEM LEVEL**
- ☐ **2. SPACE CRAFT**
- ☐ **3. SUBSYSTEM**
- ☐ 4. MODULE
- ☐ 5. EXPERIMENT
- ☐ 6. INSTRUMENT
- ☐ 7. COMPONENT
- ☐ 8. OTHER

MODEL

- ☐ 1. ENGINEERING
- ☐ 2. STRUCTURAL
- ☐ 3. THERMAL
- ☐ 4. PROTOTYPE
- ☐ 5. PROTOFLIGHT
- ☐ 6. FLIGHT
- ☐ 7. SPARE
- ☐ 8. OTHER

WORK CATEGORY

☐ 1. VIBRATION	☐ 9. LEAK	☐ 17. INSTRUMENTATION	☐ 25. COATINGS
☐ 2. SHOCK	☐ 10. TEMPERATURE	☐ 18. SAFETY	☐ 26. RADIATION
☐ 3. ACCELERATION	☐ 11. HUMIDITY	☐ 19. FIELD SUPPORT	☐ 27. BLANKETS
☐ 4. STATIC LOAD/BEND	☐ 12. THERMAL-VACUUM	☐ 20. MAINTENANCE	☐ 28. CLEAN ROOM
☐ 5. SPIN/BALANCE	☐ 13. THERMAL-BALANCE	☐ 21. TRANSDUCER CALIB.	☐ 29. INTEGRATION
☐ 6. MODAL SURVEY	☐ 14. MAGNETIC	☐ 22. ACOUSTIC	☐ 30. SLIP
☐ 7. WT-CG-MOI	☐ 15. RECERT	☐ 23. OPTICAL	☐ 31. FLT HDW DESIGN
☐ 8. TV-BAKEOUT	☐ 16. RFI	☐ 24. DEPLOYMENT	☐ 32. OTHER

	(LAST NAME)	FI	(Area Code, Exch. Extn.)	ORG CODE:	
DESIGNER/EXPER:					
TEST ENGINEER:					SIGNATURE DATE
VERIFICATION MGR:					
SECTION HEAD:					
PROJECT MGR:					SIGNATURE DATE
FINANCIAL ANALYST:					

○ CONTRACTOR VERIFICATION MGR? If contractor Verification Manager, then Government representative must sign

Government Representative, Title

Signature, Date

Figure 3. Work Directive Form (Back)

GODDARD SPACE FLIGHT CENTER
MECHANICAL SYSTEMS CENTER
CODE 549

WORK DIRECTIVE (WD)

HAZARDS

TEST SPECIFICATION

TEST PLAN/OTHER

CLEANLINESS REQUIREMENTS

NOTES:

OHA/Safety - The project shall prepare an Operations Hazard Analysis (OHA) which identifies the safety hazards involved in testing, and what measures will be taken to minimize risk to personnel and hardware. The project shall perform the analysis for the test item. Also, the Code 549 test engineer shall perform an OHA for the facility and its effect on the test item. The degree of complexity of the OHA depends on the size, weight, and cost of the test item, and may consist of a visual analysis for simple components. Safety requirements are identified in the *Mechanical Systems Center Safety Manual*, DOC #5405-048-98. This document will be provided by the EPE.

Handling - The project shall identify any special precautions needed during transport, installation, and removal of the test item. This shall include sensitivity to contamination and electrostatic discharge, and whether it contains radioactive or hazardous materials, high pressure tanks, and/or explosive devices. These precautions shall be provided to the cognizant Code 549 personnel responsible for the test.

5.5 Test Reports

At the conclusion of each test, the Code 549 engineer will prepare a report that describes the as-tested configuration, test data, results, and conclusions. An initial report that includes preliminary test data will generally be available within one week. The final report will be available for distribution within 30 days after completion of a simple test, and up to 60 days after a complex test. One copy of the report will be supplied to the project lead technical engineer.

6.0 Funding Requirements

There must be funding available for all integration and test work before a WD can be issued by Code 549. Without the WD, work cannot begin. It is imperative that a valid funded fiscal job order number be in the GSFC Financial Management Division's computer in order to generate the WD. This applies to all GSFC projects, reimbursable work, and suballotments.

6.1 Planning For Integration And Testing

Code 549 generates an estimate for the work prior to issuing a WD. This estimate is only as good as the requirements provided. It is of utmost importance that the customer provide as much detail as possible so an accurate cost estimate can be generated. Good planning is absolutely necessary in order to keep the cost from escalating.

6.2 Fiscal Job Order Number (FJON)

Each WD requires a funded FJON in the GSFC Financial Management Division’s computer before it can be issued. This FJON is a 12-digit number with the last two digits being -69, designating it for integration and test work. The number can be established only when 506 funding exists.

6.3 Integration And Test Charge Backs

The labor, materials, and travel costs are charged back to the FJON on a monthly basis. This is documented in the Financial Management Division Report ITT101A, and available from your EPE and the GSFC Project Resource Analyst. This report gives a detailed costing for each WD, and a summary costing for each FJON. Additional cost reports generated by the Code 549 support service contractor, on a weekly basis, are also available from the EPEs.

6.4 Integration And Test Rates

The rates charged for technician and engineering support are established at the beginning of each fiscal year and approved by the Director of Applied Engineering and Technology. These rates are for the Code 549 support service labor only. There is no direct charge for facility usage or civil service labor for all GSFC, suballotments, and Government reimbursable work. Integration and test work estimates are not fixed price estimates, and may change as requirements change. It is very important to provide all requirements when estimating I&T costs, and to maintain schedule in order to keep these costs from escalating.

7.0 Special Considerations

Customers of the Environmental Test Engineering & Integration Branch must be aware of a number of considerations. The following paragraphs attempt to highlight the most important issues. In all cases, it is highly recommended that engineers and managers contact Code 549 Branch personnel as early as possible before coming into the Branch for work. Prior planning is by far the most important activity needed for efficient and effective I&T tasks.

7.1 Material Selection

In general, the selection of materials comprising GSE (and sometimes space-flight hardware) is most important for thermal vacuum testing. Cables, electrical connectors, fixtures, fasteners, and other elements that comprise the “unit under test” play critical roles dictating the success of the test and the final test costs. Under all circumstances, materials that strongly outgas under vacuum must be avoided. Failure to conform to these requirements can lengthen the test time, substantially increase its cost (due to chamber time and post test cleanup); and under extreme cases, contaminate the flight hardware. Please consult with Code 549 personnel well in advance of fabricating or specifying these kinds of items. For reference purposes, NASA Reference Publication 1124 offers outgassing data for a large number of commercial materials.

7.2 Lead Times

Lead times required to support testing can be significant. For example, a thermal balance test requiring a complex thermal fixture could take 6 months or longer to prepare. Strength tests of nearly any complexity on flight hardware will take at least 3 months to prepare, and could take 6 months to prepare in cases of complex actuator or High Capacity Centrifuge-based tests. In general, larger or more complicated test items require longer preparation lead times. Failure to properly budget this time, or failure to address these problems early will impact the program's cost and schedule. The best way to address these problems is to consult with Code 549 engineers well in advance of your test requirement dates.

7.3 Test Environment Accuracy

Users of the test facility should be aware of certain issues when planning, designing, and executing environmental testing. One issue is accuracy. Each test environment has allowable accuracy and variance tolerances. Some of these tolerances can be quite large. For example, random vibration spectrum input generally has allowable tolerance bands of $\pm$ 3 dB. Effectively, the actual level at a given spectrum point is allowed to be half or double what is specified, a substantially large variance. Another issue is generation of unwanted environments coincident with the desired environment. For example, vibration shakers generate stray electromagnetic fields and cross-axis vibration. Each environmental test will have a different set of issues. The user must understand these issues so proper test planning and protection of vulnerable hardware can be assured, while enabling improved interpretation of test results and test data. Direct contact with the facility engineers early in the planning process will help assure quality test products.

7.4 Schedules

The Branch works a normal 8-hour work day. An exception is the thermal vacuum test group that supports test chamber control on a 24-hour, 7-day per week basis. However, activities related to setting up a thermal vacuum test still must be accomplished during normal work hours. If requested, overtime and multi-shift work can be supported for a short, high priority task. The customer needs to be aware, however, that overtime work will cost the project increased hourly charges. Also, extended overtime requirements will be difficult to support due to constraints on total amounts of overtime allowable, and due to personnel constraints. Requests for overtime support must be made in advance of the requirement. Normally, two day's notice is sufficient for planning purposes.

7.5 Facility Access

Facilities used in the I&T process are generally not reserved in advance for a particular project item. Experience shows that hardware schedules are so changeable that test schedules made in advance are usually unreliable. With other projects vying for the same facility, it makes little sense to "hold" a facility when schedules slip. Instead, the Branch uses the first-come, first-served philosophy which has been shown to work well over the long term. On a case by case basis, other arrangements are possible; managers should be aware that costs usually increase when these requests are fulfilled.

The test and integration facilities and the related personnel are usually quite busy. It is not unusual to have scheduling conflicts between competing projects. Resolution of these conflicts is normally handled locally between facility engineers and managers, lead project engineers, and the assigned EPE. Normally, there is a hierarchy of conditions that will dictate the resolution: launch date, tests in progress, relative project flexibilities, budgets, and test complexity and detailed requirements normally play the most important roles. Under rare conditions, resolution of the conflict will be handled by higher level managers within Code 500 and the project.

7.6 Contamination

Projects must inform Branch engineers concerning requirements for prevention of molecular and particulate contamination so that appropriate handling and storage precautions can be planned. Inappropriate specifications of contamination needs could result in increased costs and schedules or damaged hardware. If you specify requirements less stringent than what is needed, your payload risks contamination. On the other hand, if more stringent requirements are specified than actually required, I&T costs will increase unnecessarily and the schedule will be extended. It is strongly suggested that project engineers properly understand their contamination requirements and clearly communicate those requirements to Branch engineers. The Branch will generate the necessary implementation plans and budgets for specific projects when requested.

Another issue of contamination is related to facility contamination. Through the use of improper materials, project hardware could well contaminate the test facility (i.e., thermal vacuum chambers). Under circumstances of gross contamination, the project will pay to have the facility cleaned to minimum standards.

Minimum levels of cleanliness must be maintained for all hardware while in a clean room. This means that project hardware must be compatible with other hardware coexisting in the clean room even if specific project requirements don’t dictate it. This may be a cost item for the project.

In all cases, early and continuous communication with Code 549 personnel will help to alleviate any problems associated with these issues.

7.7 Safety

Safety is always of paramount interest to Code 549. Protection of people, flight hardware, and facilities (in that priority) takes precedence over all other requirements. Consequently, Code 549 management must be convinced that all potentially hazardous activities are being properly executed, and proper protection is being implemented. Any time a potentially hazardous activity is planned, project personnel are strongly advised to talk with Branch personnel early so that a reliable safety assessment can be made. Without proper planning and precautions, the activity will not be supported.

In order to assess any safety issue, the Branch may require an in-house analysis of the condition. The project is responsible for providing funds to do this. Examples of issues of particular concern are: hazardous gasses and liquids (such as ammonia, chlorine, and caustics), radioactive materials, flammable materials, stored energy in the forms of spinning masses, pressurized systems, sprung systems, batteries, and chemicals (explosives). Unusual handling or lifting requirements are also of concern. Stability, controllability, and strength of the lifting system must be analyzed.

7.7.1 Safety Manual

The Mechanical Systems Center publishes a Safety Manual which discusses some of these issues in greater detail. Project engineers working in the facility complex are encouraged to obtain a copy and read and understand it.

7.7.2 Risk Assessments

When deemed appropriate by the Branch head or Branch engineer, Code 549 will perform a detailed risk assessment study prior to executing an activity in question. The assessment will define specific risks, estimate likelihood of the risk, and describe the likely result of the risk. As part of the study, the Branch will make recommendations on how to reduce the risk, or eliminate the adverse outcome of the risky event.

7.7.3 Safety Procedures

Under certain conditions, a safety procedure must be written to address the activity needed to alleviate a specific risk. Code 549, in conjunction with Code 205 and project personnel, will write the safety procedure. Code 205, Code 549, a project representative, and others if circumstances dictate, will approve the procedure.

7.8 Cost Drivers

There are certain issues which, if not properly handled, serve to increase customer costs. These cost drivers are described briefly below.

7.8.1 Early Involvement

In general, the best way to assure minimum cost is to bring Code 549 personnel on board as early as possible. Having a Branch representative work with the project early provides several important benefits. Early understanding of project requirements will allow timely and efficient preparation for future activities. Last minute preparation tends to increase overall costs through overtime and less than optimal support systems design. Branch personnel can educate project personnel regarding issues and limitations important to the specific I&T process. Such education can help prevent unnecessary purchases, influence how a test or activity is designed, and assist in specifying the proper level of requirements.

7.8.2 Contamination Requirements

Strict contamination requirements will certainly increase costs. Special handling procedures, special materials, clean room use, repeated cleaning, and stringent vacuum chamber cleanliness requirements all serve to increase costs. Projects should ensure that the appropriate level of contamination avoidance is specified for their program.

7.8.3 Facility Modifications

Costs will increase any time modifications to a facility are needed to accomplish a specific activity. Here again, early involvement of Branch personnel is advantageous to assess facility limitations and develop possible plan-arounds, which might preclude the need for facility modifications.

7.8.4 Extensive Overtime

Late and slipped schedules are usually made up in the late I&T phase. Often, insufficient time is available to efficiently execute an activity. When this happens, the only recourse is to use overtime. Extensive overtime will quickly drive up costs. Projects are advised to allocate sufficient time for the I&T phase to allow the work to occur during normal hours. Early planning and Branch involvement can help alleviate this problem.

7.8.5 Bakeout Criteria

Flight hardware for payloads sensitive to molecular contamination require bakeouts. Bakeouts can be the largest expense item of an environmental test program. It is strongly recommended that project engineers carefully select the bakeout requirements. Overly stringent requirements are clear cost drivers. Proper planning of the bakeout sequence can also reduce costs. For example, if allowed by schedule and technical constraints, combining hardware for bakeouts will certainly reduce costs.

7.8.6 Instrumentation

In general, numerous channels of response instrumentation will drive up costs. Costs of providing, calibrating, applying, wiring, and removing the sensors, coupled with those of acquiring, analyzing, and reporting the data will increase costs. Projects should acquire all the data they need, but make sure they need all the data they acquire.

7.8.7 Functional Tests

Functional checks during and between tests are standard practice. However, when these checks are exceedingly long, or occur very frequently, or require partial or complete disassembly of the test setup, costs will be driven up. Project should ensure that the functional checks specified are the minimum reasonably useful.

7.9 Hardware Handling

The Branch in-house guidelines require that only Code 549 personnel shall operate the MSC cranes. Further, a certified hydraset operator must use an in-line hydraset for all lifts involving flight hardware. Advanced planning is required to avoid having people stand around while the appropriate equipment and operators are obtained.

7.10 Ground Support Equipment

Extensive ground support equipment will dictate involvement of Code 549 personnel in planning its placement. Project personnel should always be aware that, generally, they are not the only project using the facility. They may be required to take some specific action, or agree to certain limitations so that work for other projects can proceed.

7.11 Storm Codes

A system of weather codes has been established and is followed in the facility complex. The system is designed to warn project personnel and facility operators of specific hazardous weather conditions which might adversely affect facility operations. The system is set up to protect critical hardware and, to a lesser extent, personnel. The concern expressed by these codes is that sudden and unexpected power outages, power fluctuations, and power transients could occur. Such occurrences could generate undesirable conditions such as vibration transients, strand a payload on a crane hook, or cause a vacuum chamber to go down. Under the worst code, code three, in-house regulations dictate that certain operations be stopped. The Code 549 Branch head and a project representative must sign a formal waiver before operations can proceed during code three conditions. Each kind of operation (lifting, vibration, load tests, etc.) will have different procedures and restrictions regarding the storm codes.

7.12 Proof tests

All lifting hardware and critical hardware fixtures must be proof tested prior to being used for flight hardware. In addition to proof test requirements, the Branch requires that any critical lift be analyzed for lift stability. Project engineers or Code 549 can perform this analysis. Branch personnel are generally aware of these requirements and will help guide project personnel though the requirements maze.

8.0 Facility Upgrade Requirements

Occasionally a specific project test or integration requirement cannot be met by the current facilities. In general, because of some project-specific characteristic or requirement such as size, weight, special handling, test level requirement, accuracy, or data requirement, a modification to a facility or multiple facilities is required. In instances such as this, early planning and Branch personnel involvement is critical to successful and efficient execution of the activity.

9.0 Security And Building Access

Access to the Building 7/10/15/29 complex is restricted after normal working hours by a Key Card door lock system. Key Cards are issued by the Goddard Security Branch. Requests for Key Cards are made with a Key Card request form. The form is signed by the building complex Facilities Operations Manager (FOM) and by the Code 500 Security Coordinator. All personnel needing access to the complex for after hours test support must obtain a Key Card. For external personnel

(GSFC Visitors), temporary Key Cards with given expiration dates will be issued. Please coordinate with the EPE in advance of your work to ensure proper access.

10.0 Customer Feedback

Suggestions concerning the improvement in the quality of the support from the MSC during the test program is important. At the conclusion of each test activity, an evaluation sheet will be provided by the Code 549 test engineer for your comments. It is requested that these comment sheets be completed prior to your departure.

APPENDIX - B: ABBREVIATIONS, ACRONYMS AND SYMBOLS

ABBREV SYMBOL	TRANSLATION
"	inch
'	foot
<	less than
>	greater than
%	percentage
µ	micro
Å	angstrom
A	ampere
AC	alternating current
A/C	air conditioning
amp	ampere
AN	American National
ANSI	American National Standards Institute
B or Bldg	building
˚C	degrees Celsius
CCTV	closed circuit television
C/F	cold finger
CFM or cfm	cubic feet per minute
CG	center of gravity
CIA	Calibration-Integration-Alignment
cm	centimeter
col	column
CRT	cathode ray tube
D	diameter
dB	decibel
DC	direct current
DEC	Digital Equipment Corporation
dia	diameter
dim	dimension
ea	each
EMC	electromagnetic compatibility
EMI	electromagnetic interference
˚F	degrees Fahrenheit
FM	frequency modulation
fpm	feet per minute
FRF	frequency response function
ft	foot or feet
g	gram

ABBREV SYMBOL	TRANSLATION
g	unit of acceleration
gal	gallon
GN_2	gaseous nitrogen
GSFC	Goddard Space Flight Center
H	height
HCC	High Capacity Centrifuge
Hdwe	hardware
HEPA	high efficiency particulate air
HgXe	mercury xenon
Hp	horsepower
HP	Hewlett-Packard
Hr or hr	hour
HST	Hubble Space Telescope
HVAC	heating, ventilation, and air conditioning
Hz	Hertz (cycles per second)
IIF	instrument interface flange
In or in	inch
ITD	Instrument Test Dewar
IVS	instrument vacuum space
JSC	Johnson Space Center
˚K	degrees Kelvin
KB	kilobyte
Kg	kilogram
Kpa	kilopascal
KSC	Kennedy Space Center
KVA	kilovolt ampere
KW or Kw	kilowatt
L or l	liter
L	length (depth)
Lb or lb	pound
LHe	liquid helium
lit/sec	liter per second
LN_2	liquid nitrogen
LVDT	linear variable differential transformer
M or m	meter
MAP	Microwave Anisotropy Probe
max	maximum
MB	megabyte

APPENDIX - B: ABBREVIATIONS, ACRONYMS AND SYMBOLS

ABBREV SYMBOL	TRANSLATION
MB C220	MB C220 vibration exciter
MicroVAX	DEC computer
MIL STD	Military Standard
min	minute
Mitoc	communications system
MLI	multi-layer insulation
mm	millimeter
MOI	moment of inertia
MPMF	Mass Property Measurement Facility
mV	millivolt
NA or N/A	not applicable
NASA	National Aeronautics and Space Administration
NASTRAN	finite element modeling program
NIST	National Institute of Standards and Technology
nom	nominal
NSI	NSI Technology Services, Inc.
nT	nanotesla
OASPL	overall sound pressure level
ohm	unit of resistance
oz	ounce
pa	pascal
PC	personal computer
PCM	pulse code modulation
pH	measure of acidity
P/L	payload
PLC	programmable logic controller
POI	product of inertia
PRT	platinum resistance thermometer
PSD	power spectral density
psi	pounds per square inch
psig	pounds per square inch gauge
PVC	poly vinyl chloride
QCM	quartz crystal microbalance
rad	radian
rad/sec	radians per second

ABBREV SYMBOL	TRANSLATION
RF	radio frequency
RFI	radio frequency interference
RGA	residual gas analyzer
RH	relative humidity
RM or Rm	room
RMS or rms	root-mean-squared
Rolm	GSFC telephone system
RPD	rapid pump down
RPM or rpm	revolutions per minute
RPS or rps	revolutions per second
RTV	room temperature vulcanizer
SC	solar constant
SCA	Spacecraft Checkout Area
scfm	standard cubic feet per minute
SES	Space Environment Simulator
SMTF	Spacecraft Magnetic Test Facility
SPL	sound pressure level
sq	square
SSDIF	Spacecraft Systems Development & Integration Facility
STS	Spacecraft Transportation System
t	thickness
T	tesla
T/C	thermocouple
temp	temperature
torr	1/760 of a standard atmosphere
TQCM	thermoelectric quartz crystal microbalance
UD	Unholtz-Dickie
UV	ultraviolet
V	volt
VA	volt ampere
Vac	vacuum
vol	volume
W or w	watt
W	width

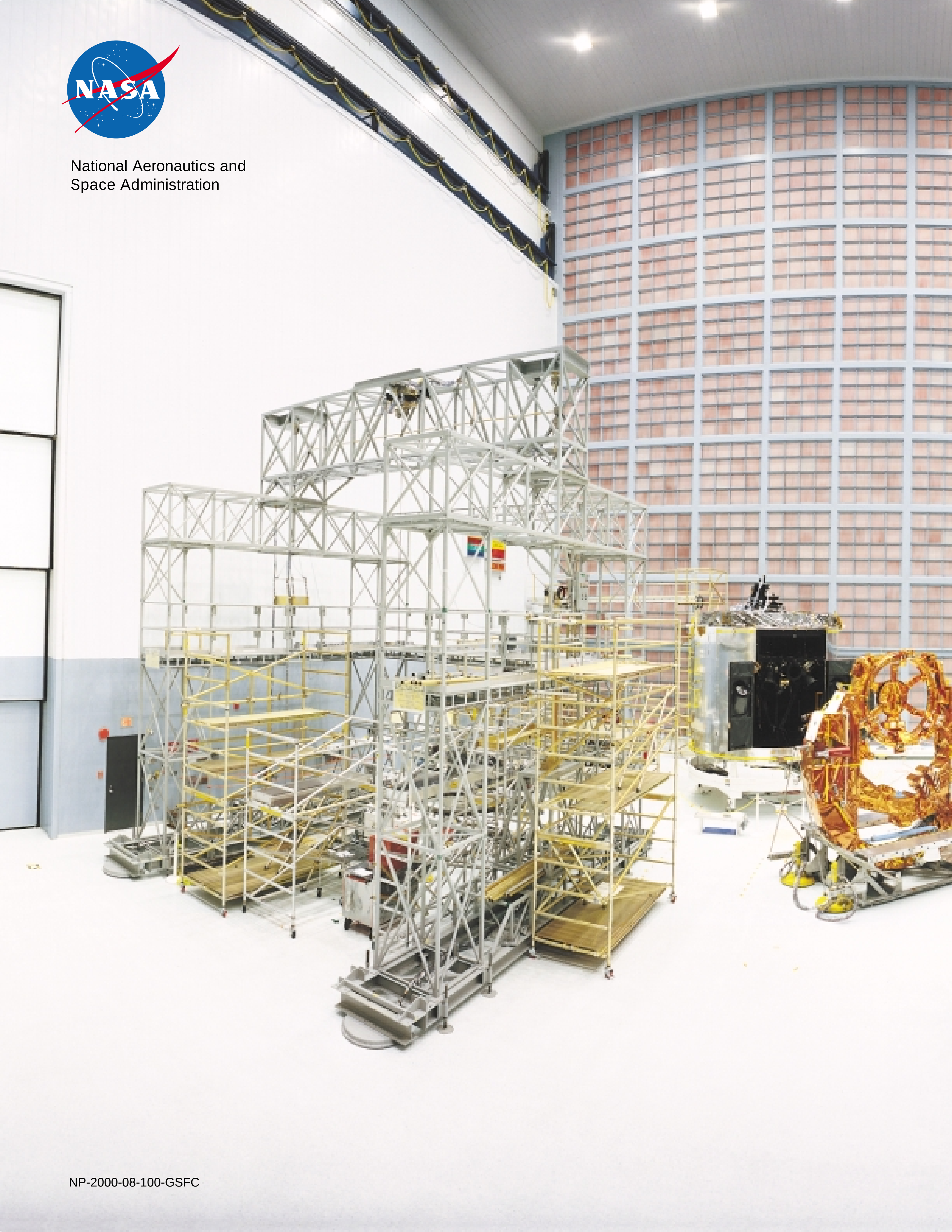
APPENDIX - C: METRIC/ENGLISH CONVERSION FACTORS

METRIC TO ENGLISH UNITS			ENGLISH TO METRIC UNITS		
Convert From:	**To:**	**Multiply By:**	**Convert From:**	**To:**	**Multiply By:**
amp/centimeter^2	amp/inch^2	6.45	amp/inch^2	amp/centimeter^2	0.155
amp/decimeter^2	amp/foot^2	9.09	amp/foot^2	amp/decimeter^2	0.11
Celsius	Fahrenheit	[C x (9/5)] + 32	Fahrenheit	Celsius	[F-32] x (5/9)
centimeter	inch	0.3937	inch	centimeter	2.54
centimeter^2	inch^2	0.155	inch^2	centimeter^2	6.452
centimeter^2/liter	foot^2/gallon	0.0041	foot^2/gallon	centimeter^2/liter	245
gram	ounce	0.0353	ounce	gram	28.329
gram	pound	0.0022	pound	gram	453.6
gram/centimeter^2	ounce/inch^2	0.228	ounce/inch^2	gram/centimeter^2	4.39
gram/liter	ounce/gallon	0.133	ounce/gallon	gram/liter	7.5
gram/liter	troy ounce/gallon	0.125	troy ounce/gallon	gram/liter	8
kilogram	pound	2.205	pound	kilogram	0.4536
kilogram	ton	0.0011	ton	kilogram	907.2
liter	gallon	0.2642	gallon	liter	3.785
meter	inch	39.37	inch	meter	0.0254
meter	foot	3.281	foot	meter	0.3048
meter^2	foot^2	10.76	foot^2	meter^2	0.0929
meter^3	foot^3	35.31	foot^3	meter^3	0.02832
meter^2/liter	foot^2/gallon	40.82	foot^2/gallon	meter^2/liter	0.0245
micron	microinch	39.4	microinch	micron	0.0254
micron	inch	0.0000394	inch	micron	25400
micron	mil	0.0394	mil	micron	25.4
millimeter	inch	0.0394	inch	millimeter	25.4
newton	pound (force)	0.225	pound (force)	newton	4.45
newton-meter	inch-pound (force)	8.85	inch-pound (force)	newton-meter	0.113
newton-meter	foot-pound (force)	0.7376	foot-pound (force)	newton-meter	1.356
pascal	pound/inch^2 (psi)	0.000145	pound/inch^2 (psi)	pascal	6895
pascal	torr	0.0075	torr	pascal	133.32
watt	horsepower	0.00134	horsepower	watt	745.7

APPENDIX - D: DECIMAL PREFIXES

Prefix	Symbol	Factor
atto	a	10^{-18}
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
deka	da	10^{1}
hecto	h	10^{2}
kilo	K	10^{3}
mega	M	10^{6}
giga	G	10^{9}
tera	T	10^{12}
peta	P	10^{15}
exa	E	10^{18}

National Aeronautics and
Space Administration



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